Changes in Research Management at Danish Universities and Government Research Institutes

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Foreword

During the last decade a number of changes in the management structure at Public Research Institutes in Denmark have occurred. Theses changes in the management structure are the main objects of this report, the final report from the project *Research Management under Change* (ReMaC). The ReMaC-project is one of a number of projects on research management that have been conducted at the Danish Institute for Studies in Research and Research Policy as well as other places in Denmark during this period. This report is written by the project manager of ReMaC, Kamma Langberg; while writing this report on ReMaC she has received feedback at the institute from Ebbe K. Graversen, Evanthia Kalpazidou Schmidt and Carter Bloch.

The main parts of the report consist of the background for the Danish discussion: the development within the public research sector in Denmark focussed at Danish universities and government research institutes with respect to management and a new model of research performance.

The ReMaC-project became in 1999 a part of the collaborate project REMAP and was then focussed on public research institutions. REMAP was a research partnership between Department of Management, Politics and Philosophy (MPP, Copenhagen Business School), Danish Institute for Studies in Research and Research Policy (AFSK), RISØ National Laboratory and six research based Danish companies.

On behalf of the Institute I would like to thank the partners in REMAP as well as all the research managers and researchers that have provided information to the ReMaC-project.

Karen Siune
Director
June 2003

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1. Introduction

Research is often regarded as investment in the future: research is the base for new insights, new products, new ways of living, and new ways of thinking. Better management of research can improve research performance and thereby improve the utility that society can receive from resources invested in research. *Research management* is the core issue in this report.

Research management has been discussed throughout Europe in the last decade. In this period a growing awareness of the relations between research, education and economic growth has raised. The project *Research Management under Change* (ReMaC) is one among a number of studies that have been conducted on the subject during the period.

The main aims of the ReMaC were to study the management changes within the public research sector, to develop a model of research management and simultaneously to develop methods to do so.

This includes

- A study of the concept *Research management.*
- A study of the general structure of the Danish research system focussed on Universities and Government Research Institutes (GRIs).
- A study of a number of cases, where different levels of the concept *Research management* as well as different form of managerial strategies could be investigated.
- A development of a strategy of empirical methods.
- A development of a model of research performance.

Since the project began in 1999 the discussion of the management in the public research sector in Denmark has not only increased, the government announced a reform of the public research sector in 2002. Since then, a proposal for a new law on universities has been put forward, however it is still unclear at this time (May 2003) what the resulting structure of the system after the reform will be and the effects of the reform can therefore only partly be included in this report. However experiences from earlier show that changes in rules and laws interact with traditions and former laws in such a way that the practical management depends on the (new) formal rules as well as well-established (informal) rules. The future management of the Danish public research institutions is therefore likely to be influenced by traditions, former rules, and the coming reform.

In the following two subsections the concept *research management* and some initial models together with the empirical strategy used will be presented. The

amount of research in society is dependent both of the resources addressed to research and the societal context as infrastructure and culture. Research is performed in different settings depending on the history and actual context, and research has to be transferred and eventually transformed before access can be given to it. The Danish background for the discussion, the *Danish research system,* will be described in section 2 followed by section 3 where actual management tools and systems used within the Danish public research management are presented.

In section 4 a model of Research Management that includes a model for research performance is presented and the economic perspectives of such a model are briefly discussed.

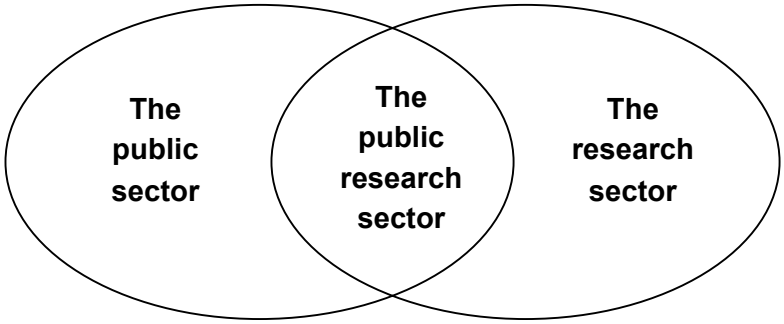
1.1 Public Research, Research Context, and Research Management

The possibilities for active management including changes in management are in general dependent on the context as well as the internal rules of the organisation that is to be managed. Management of any organisation must focus on the actual form of organisation: is it a knowledge-based organisation, a capital based organisation, or based on knowledge as well as capital? It is often useful to divide organisations into capital intensive, labour intensive, or knowledge intensive when they are analysed. Organisations that perform research can be all of these, but most of them would be labelled as knowledge intensive. The knowledge involved in research consists of two types of knowledge: knowledge similar to the knowledge possessed by other knowledge based organisations and creative knowledge necessary for the production of new knowledge, i.e., research within the actual subject area. Management of a research organisation must therefore be focussed on research performance as well as addressed to the organisation as a knowledge organisation.

The research sector in a given subject or geographical area is the total amount of organisations in the area conducting research regardless of their formal or legal status. A research organisation can be a part of a larger organisation, an institution, and it can be private or public owned, etc. The private and the public sector have different goals as well as rules, and management in the two sectors are consequently different.

The public research system as such can be viewed both as a part of the public system, or a specific part of the research system, as seen in Figure 1-1. A study of the public research sector may therefore include information about the total public sector as well as about the total research sector.

Figure 1-1: The public research sector



A study of research management may focus on the managerial system, on the managers, on the results of the management, i.e., how the management affects research performance; or it may focus on research in terms of its integration with other sectors i.e. the total public sector or the private sector. A study must also define the level of research management, i.e., answer the question: is research management:

- Management within the structural frames of the research institutions?
    - If so a study must focus on frames, i.e., rules and regulations.

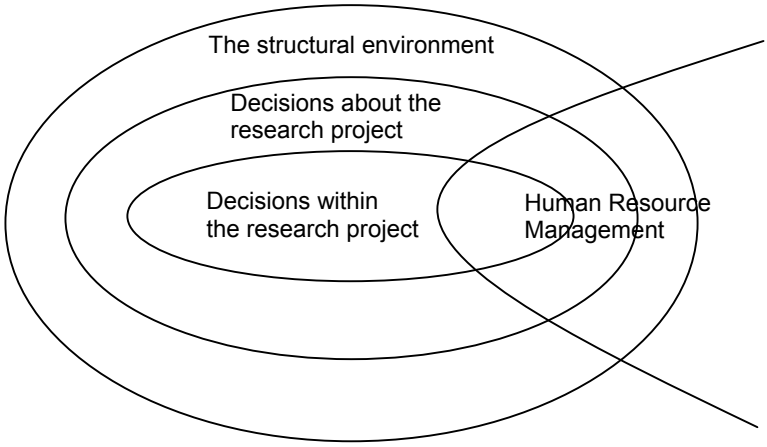
- Decisions about research projects, e.g., decisions on financial support of projects groups and institutions?
    - If so a study must focus on research managers as head of departments and deans.

- Management within research projects, e.g., decisions of what methods to use in a specific situation?
    - If so a study must focus on single research projects.

- Management of researchers, e.g., human resources management?
    - If so a study must focus on relations between researchers and managers and the actual human resource policy.

The relations between the different levels of the concept research management are seen in Figure 1-2 (Langberg 2002b). The figure shows the initial model of ReMaC, where all levels were addressed.

Figure 1-2: Different levels of research management



The structural environment or context as seen in Figure 1-2 can be understood as relations between other parts of society and/or collaboration partners.

The context plays a number of roles when seen in a management perspective: first the managers have to manage within the context which includes collaboration, fundraising, transformation of knowledge etc.; second the management role as such is affected by management styles and systems from other sectors. Lately, the trend has been that management tools and systems developed in the private sector have entered into the public sector (local and central government sector) and then into the public research sector.

Many (senior) researchers in Denmark as well as in other countries are their 'own managers', e.g., they work autonomous; either alone or as managers of minor projects within a certain university structure with heads of departments etc. In this case the individual university researcher has to react to changes and pressures from the outside, and the focus must be at the individual researcher. This was a main focus in the study of Morris (2001, 2002) where university scientists, administrators and support staff were interviewed. She reported the *pressures on the university researcher* as:

- New development in science
- Career pressures
- Global competition
- Diversifying funding sources
- External policies

Some researchers in knowledge management and research have focussed on concepts such as *trust* (Huemer et al. 1998; Wenneberg, 2002). The researchers (as well as others) have to *trust* the manager - and the other way around - otherwise the management will not succeed neither in the internal management (back-office) nor in managerial relations with the outside, e.g., the private sector or other research institutions (front-office). One could argue that the idea of *trust* is complementary to the ideas of research management within a *principal-agent perspective* because the relations between the principal and the agent are based on asymmetrical information that is not shared.

Research environments differ in a number of ways partly as a consequence of the management, partly due to traditions etc. This implied that a number of case studies would be one possible way to enlighten the concept, research management.

In Denmark, Bo Jacobsen et al. (2001) performed a study of 15 university environments, a study that showed a very large difference between departments with respect to research performance as well as to the working environment. Later, Graversen et al. (2002) conducted a study of 15 '*dynamic and innovative research environments*' in order to identify the characteristics of this kind of environments.

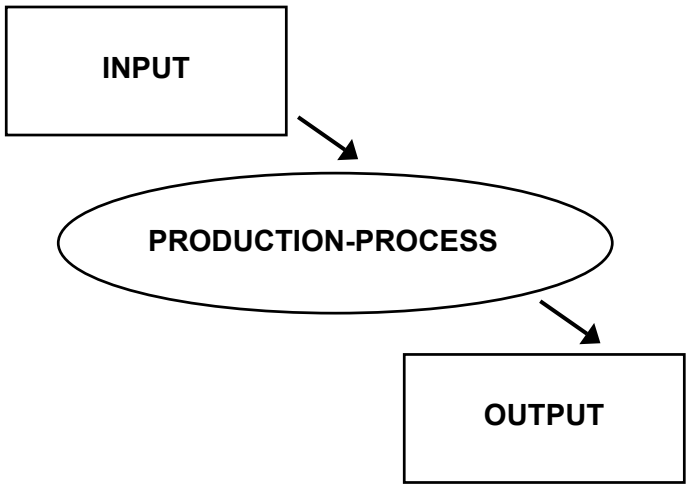
1.2 The Initial Models of Research Performance

The societal reason for interests in research management is that better research management may improve research performance and thereby improve economic growth in the society at a number of levels.

The core of the problem is research performance, and models of research performance are therefore essential to the understanding of the concept, research management.

The simplest form of a model for research performance is a production function as seen in Figure 1-3: This model focuses on input to the production-process and output from the process, in the research case the production-process is a research-process, and the management problem is the improvement of the research-process in such a way that the value of the output relative to the input is growing.

Figure 1-3: A production function

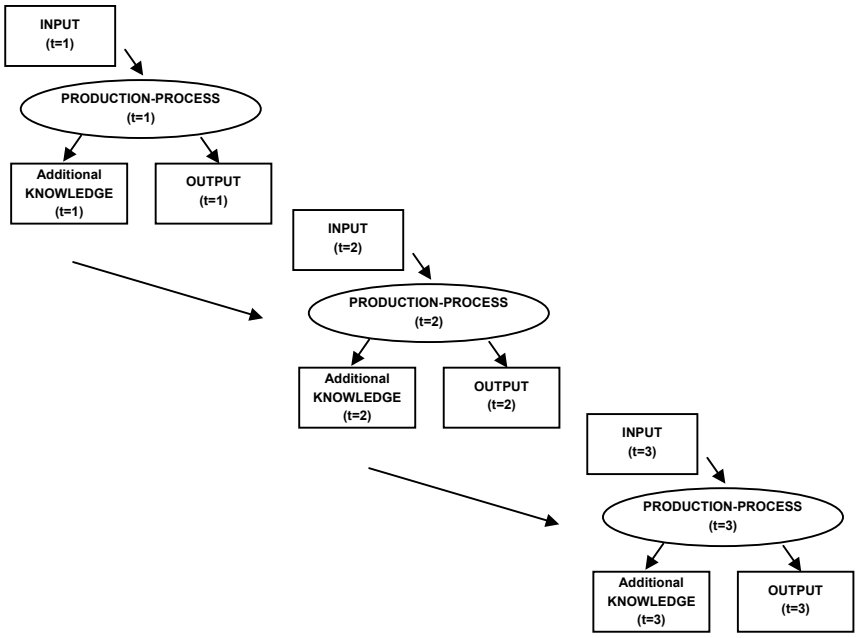


One major problem with this model is the difficulty in identifying inputs as well as outputs; another problem in the simple model is that the model implies that input can only be used once.

Basically the model is an industrial model; it implies that a limited number of inputs such as labour, raw material and capital are used in the production of goods (and services). The capital is not totally used within a period, but if its value is to be maintained (not decreasing), investments are needed; labour well as raw materials are used (or converted) totally into the outputs.

Other models focus on research performance as an ongoing process, where a continuative knowledge flow is growing and additional knowledge as a consequence enters into the production function as input as seen in Figure 1-4. In this case growth of knowledge and the growth of the amount of (research) results will be reflected in a growing knowledge base. This growing knowledge base can be used and reused within the organisation several times.

Figure 1-4: A production function in three periods - with additional knowledge as input.



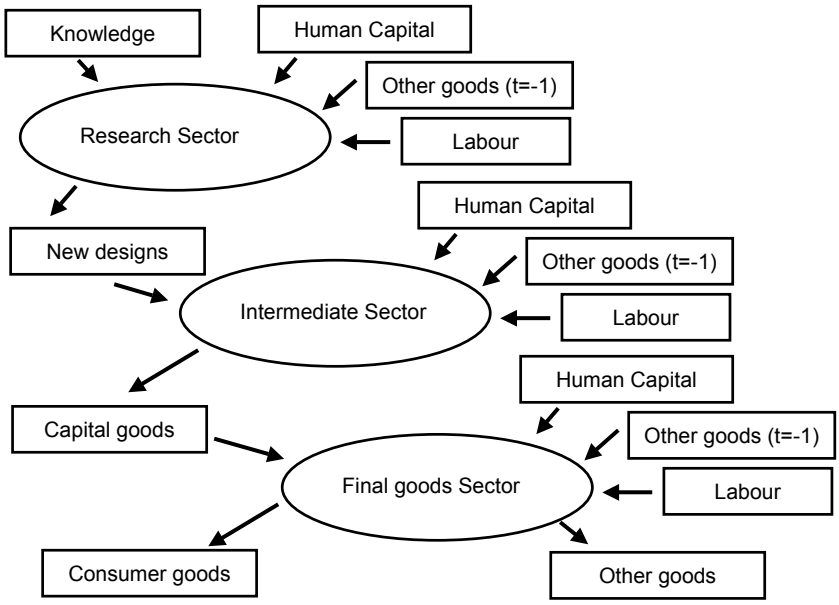
An example of such a model is Romer's growth model with endogenous technical change (Romer, 1990), Romer describes technical change as "*improvement in the instructions for mixing together raw materials*" and "*instructions for working with raw materials are inherently different from other economic goods*" these instructions are transferable knowledge, and they can be given again and again. Romer's basic model consists of three sectors:

- The research sector that produces knowledge and design (the sector in focus in this report).
- The intermediate-goods sector that produces producer-durables based on knowledge and design.
- The final-goods sector that produces the final output.

This chain of sectors where output from one sector is input in another can be found within one large organisation; the reason for the sector division is that it allows Romer to introduce two kinds of human capital in the model: the kind used to produce knowledge and the kind used in the final production. Romer uses the phrase *non-rival good* to describe technical changes, where purely non-rival goods have the property that its use by one in no way limits its use by another. By

definition public goods are non-rival, and one could say that Romer therefore treats research knowledge as a public good. The model is (as most growth models) a model concerned with the analysis of production at the national level, and it is relevant at the structural level seen in Figure 1-2. The structure of the Romer model is seen in Figure 1-5.

Figure 1-5: Structure of the Romer model



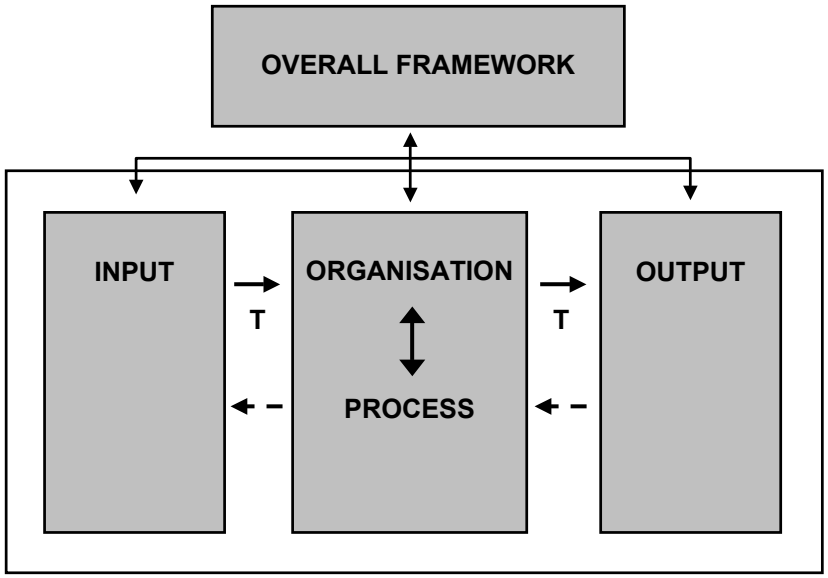
The overall focus in ReMaC is changes in research management, e.g., how to improve research performance. Performance can be improved in a number of ways, of which some can be regarded as management tools or management systems built on experience as well as on theoretical considerations. Among the tools used within the research sector and presented later in this report is *Benchmarking* (see section 3.3) and among the management systems, *Total Quality Management* and *Knowledge Management* (see section 3.1 and 3.2).

Evaluations of public research institutions have been widely used in Denmark within the last ten years where both the number of institutions and scientific areas that are evaluated as well as research on evaluations and their standards is growing (Borum and Hansen, 2000 can be seen as one example of the latest).

Kalpazidou Schmidt presented in 1996 a Model for Studies of Research Environments (MSRE) that later was further developed (Kalpazidou Schmidt, 1996 and 2002). The MSRE comprises - besides studies of input and outcome – studies of socio-economic factors as well and divides the transformation (from input to outcome) into two categories e.g. the *organisation* and the *process* taking place in research environments.

Consequently, the model is not a simple input-output model but takes into consideration the process and the organisation as well and opens up for the “black box” of conditions for research activities and processes. Even conditions that are found outside the research environments have an indirect, though significant influence on research activities and outcomes, according to the MSRE-model. An illustration of the model for studies of research environments is presented in Figure 1-6.

Figure 1-6: A model for studies of research environments



The overall framework in the MSRE-model consists of the socio-economic factors that are influencing the research environments such as the labour market for academics, research policy, and requirements for academic positions.

Kalpazidou Schmidt places demography, history, human and financial resources, and physical environment (of research departments) as *inputs* to the first transformation process (T).

The *organisation* in her model is defined by the organisational structure; i.e., infrastructure, the relationship between graduate/postgraduate programmes, communication system and continuity/renewal of the research environments organisation. The *process* is defined by activities/distribution and use of time; i.e., research activities (field, quantity, quality), research climate/milieu, conditions for research, research traditions, communication patterns, education and socialisation of researchers, national/international networks and mobility issues.

Organisations transform (T) through a process an input to an *outcome* that is constituted by dissertations, publications, citations, postgraduate students, distribution of results, rewards/prizes/patents, and engagement in public debate/society.

Elements of the process and organisational elements interact. The preconditions of the research process and production are defined by the structure of an organisation, but in the long run structures can be influenced and changed by processes as well as by other external factors. The MSRE-model focuses consequently also on the relation between science and society and emphasizes the societal factors influence on research and vice versa.

A study like *Research Management under Change* (ReMaC) must focus on the management issues, i.e., the 'black box' between input and output. This 'black box' must be seen in a context and a dynamic perspective as well. A dynamic model of research performance must include an individual level reflecting the changing interests of the individual researcher, an organisational level reflecting the change in the knowledge base in the research environment (institution), and changes in the outside world, where the focus is at the organisational level. The final model of the study that reflects this is found in section 4.

1.3 The Empirical Strategy of the study

The main aims of the project were to study the management changes within the public research sector, to develop a model of research management and simultaneously to develop methods to do so.

The empirical methodology was built on the different initial theoretical models of research management as well as experience from a study of the Danish Government Research Institutes (GRIs) in 1998 (Kallehauge, Kindtler & Langberg 1998).

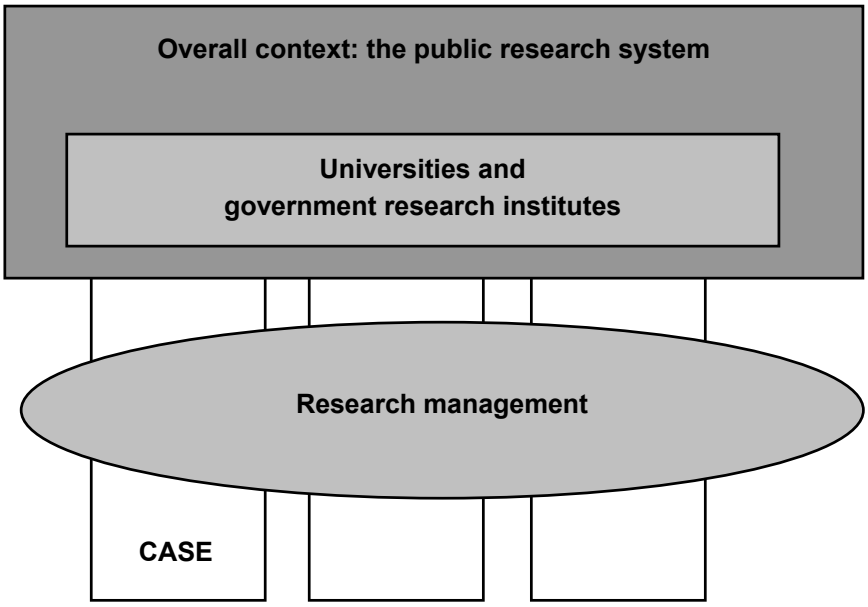
It followed from the initial theoretical models of research management that the key-information in the study would be information from research managers and researchers on research management. It also followed that investigation of the overall changes in the system was necessary if the information on research management should be induced in a relevant context. Therefore the system as such, the changes in the system as well as attitudes to changes along with the key issue *research management* had to be described.

The core concept was *research management* and this is the primary target and level.

- In order to investigate *research management* a number of researchers and research managers would be interviewed directly on the issue. This is the first level.
- In order to place the investigation of *research management* in a relevant context a number of cases would have to be studied. Those cases form the second level.
- In order to place the case studies in a relevant context the overall system as such would have to be described. This is then the third level.

This structure is seen in Figure 1-7.

Figure 1-7: The structure of the empirical study



None of the initial theoretical models could be formulated in such a way that specific hypotheses could be tested directly. The study is therefore explorative and model/hypotheses generative.

In the study from 1998 three main sources of information were used:

- Secondary information accessed from accounts, budgets, homepages, etc.
- Primary data accessed from qualitative interviews with directors and members of boards (mostly presidents) at the studied institutes.
- Primary data accessed from a (paper-based) survey of all researchers at the institutes that were studied.

One of the experiences from the qualitative interviews in 1998 was that the design with open, unstructured, and taped interviews provided information that could not have been accessed with a full structured face-to-face interview; the open, unstructured form gave access to comments and corrections on information from other sources, and the tape provided a security on precise statements that later were used in different analyses.

Another of the experiences was that the survey provided valid data on the distribution of the researchers by gender (checked by the R&D statistics) and age (checked in some cases by other sources as homepages of the GRI); and that the questions on attitudes on working conditions, such as the allocation of time etc., provided material that could be used in analyses of the difference of the GRIs with respect to working conditions, management etc. It also showed that the results (means, correlations etc.) were almost the same after the first 300 responses than the final results when all 999 responses were taken into account.

The questionnaire from 1998 ended with a number of fields open for text-comments. 31 percent used the open fields, some just wrote comments as "*stupid questions*" and similar but most of the answers were longer and had substantial information. They were all analysed together with other information on the issues they concerned.

All together this lead to a triple strategy of empirical methodology:

- Secondary data should come from a number of sources such as the state budgets, homepages, and other written material that all ready existed.
- Primary quantitative data in databases at *The Danish Institute for Studies in Research and Research Policy* should be used, as well as primary data collected as integrated parts of the project, e.g., information on age, gender position, and attitudes of researchers.
- Primary qualitative data on research management should be accessed from qualitative interviews with research managers and researchers, as well as written texts from the researchers that were not interviewed face-to-face.

The chosen empirical strategy is summarised in Table 1-1.

Table 1-1: The empirical strategy - sources of empirical data

Level	Secondary data, S	Primary quantitative data, P		Primary qualitative data, P	
		Data on number of researchers, gender proportion etc. N	Data on attitudes, A	Data collected via surveys, Q	Data collected via open qualitative interviews, I
1. Research management	-	-	PA1	PQ1	PI1
2. CASE Studies	S2	PN2	PA2	PQ2	PI2
3. Study of the general structure	S3	PN3	PA3	-	-

The design of the empirical strategy supported possibilities to confront information from one source with information from another in order to triangulate information on all levels.

The sources for S3, PN3, and PA3 (see table 1-1) were:

- The Danish R&D statistics (published as well as un-published material). The Danish R&D statistic follows OECD-standards.
- The study of the Danish GRIs from 1998 (Kallehauge, Kindtler & Langberg 1998; Kallehauge & Langberg 1999 and internal database at AFSK).
- The study of Danish university researchers from 2000/2001 (Langberg & Lauridsen 2001, Lauridsen 2002 and internal database at AFSK).
- Laws and other governmental material on universities and GRIs.
- Statutes from universities and GRIs.
- Information from articles and books on research management, universities and GRIs in Denmark as well as other countries.
- Visits to Norway and Ireland. In connection with the project, NIFU in Norway and Trinity Collage in Dublin were visited.

The Case studies used to collect PA1, PQ1, PI1, S2, PN2, PA2, PQ2, and PI2 (see table 1-1) were:

- *Forest & Landscape* (Skov & Landskab), a project concerning collaboration between a university department, *Department of Economics and Natural Resources* (IØSL) at *The Royal Veterinary and Agricultural University* (KVL) and a government research institute *Danish Forest and Landscape Research Institute* (FSL) were conducted in 1999 and 2000. A report was published in 2000 (Langberg, 2000), and presentations were made for the researchers all well as for members of the board. The study was based on:
    - Qualitative interviews with managers and researchers.
    - A survey conducted among all researchers at the GRI and at the department.
    - Information on prior history of the involved partners from books, articles, annual reports etc.
    - Information on accounts and budgets.
    - Information from homepages.
    - Information from a prior investigation on government research institutes conducted in 1998 (Kallehauge, Kindtler & Langberg 1998; Kallehauge & Langberg 1999 and internal database at AFSK).
    - Information from the Danish R&D statistics (published as well as not-published material).

- *Department of Social Science, Roskilde University* (Institut 8 på RUC) a study of a university department conducted in the period 2000 to 2002. A working paper (Andersen, P.B, 2002a) and a report (Langberg, 2002a) were published in 2002. The study was based on:
    - Qualitative interviews with managers and researchers.
    - A survey conducted among all researchers at the department.
    - Information on prior history of the involved partners from books, articles, annual reports, etc.
    - Information from homepages.
    - Information from an investigation of university researchers conducted in 2000/2001 (Langberg & Lauridsen 2001, Lauridsen 2002).
    - Information from the Danish R&D statistics (published as well as not-published material).

- *Risø National Laboratory*. A study of managerial tools. This study has not been separately published, but has been used as background material. This study is based on:
    - Observations during the spring 2001 when I was guest researcher at Risø.
    - Interviews of managers.
    - Information on prior history of the involved partners from books, articles, annual reports, etc.
    - Information on accounts and budgets.
    - Information from homepages.
    - Information from a prior investigation on government research institutes conducted in 1998 (Kallehauge, Kindtler & Langberg 1998; Kallehauge & Langberg 1999 and internal database at AFSK).
    - Information from the Danish R&D statistics (published as well as not-published material).

- *Department of Dairy and Food Science* (MLI), a department within a Triple Helix structure. A part of this study was presented at the Triple Helix conference in Copenhagen in 2002 and it was later published as a working paper (Langberg, 2002d). The study was based on:
    - Qualitative interviews with managers and researchers.
    - A survey conducted among all researchers.
    - Information on prior history of the involved partners from books, articles, annual reports, etc.
    - Information from accounts and budgets.
    - Information from homepages.
    - Information from an investigation of university researchers conducted in 2000/2001 (Langberg & Lauridsen 2001, Lauridsen 2002).
    - Information from the Danish R&D statistics (published as well as not-published material).

1.3.1 The Surveys

All surveys that were conducted in connection with the study as well as the general study of the researchers at the GRIs (Kallehauge & Langberg 1999) and the Danish universities (Langberg & Lauridsen 2001, Lauridsen 2002) had the following characteristics:

- They had the same general structure.
- They were addressed to researchers at all levels.
- They were total investigations, e.g. all researchers and not just a sample received a questionnaire.

All surveys included information on position, gender, age, and education (level, subject and university). This information was used as background information in general and in the statistical analyses. Information on position and gender were used to check representativeness by use of similar information from the R&D statistics. (The Danish R&D statistics databases do not include any information on age or education level).

The surveys included information on the former places of appointments this information was used in analyses of mobility of the researchers (Langberg and Graversen, 2001) as well as indicators of experience from other organisational settings.

There were sections in the questionnaires on working hours, time allocation (between research and a number of other issues), working conditions, appointment (temporary vs. not temporary contracts).

All surveys included sections with attitudes-questions assigned to a five-point likert-scale. The likert-scale used was the same in all questions from *Strongly agree* to *strongly disagree.* The questions were designed to be analysed in models with latent variables (see Appendix).

All surveys were built on the total population of researchers, as a consequence results from the surveys are highly reliable; the statistical methods were used as tools, i.e., differences were real differences and should not be corrected for possible statistical error.

All surveys included open fields for comments. Information from these fields was used in two ways: the information was coded on subject and used in qualitative analyses as well as written out in plain text. The comments were later used together with other information sources.

None of the surveys had questions on salary, because the salary in general follows the position (see section 3). None of the surveys had direct questions on outcome or output from research, e.g., number of articles or patents, mainly because the investigation included researchers from different subject areas with very different 'production-structures'.

The survey on the university researchers in 2000/2001 and the survey on MLI were web based, e.g., the researchers received a mail with a link to the questionnaire as well as a password. All other surveys were paper-based. All the paper-based surveys were coded at *The Danish Institute for Studies in Research and Research Policy*.

1.3.2 The Qualitative Interviews

All the qualitative interviews were based on interview-guides where a number of issues on research and research management were listed.

All interview studies started with a phase, where the objects of the study were transformed into issues and questions connected to the context. The interview guide was formulated in the same period where interview-persons were contacted and appointments were made. Shortly after the interview the first notes on it were made. These first notes were used in the next interviews. When all the interviews were taken, the results were induced into the case description.

The interviews were semi-structured, each interview started with a short presentation of the study and ended with a question to the interviewed like *do you have any questions to us/me?* In between the interviewer asked questions connected with the different issues, allowing the interviewed to tell stories and associate to other issues during the talk. Consequently the issues were not addressed in the same order in all the interviews and some issues were addressed several times in the same interview. All interviews were taped, in one case all tapes were written out word by word (Andersen, P.B, 2000a) and then analysed, in the other cases the tapes were used directly as a base for summaries on different issues.

1.3.3 Conclusion on Choice of Methods

The combination of quantitative and qualitative empirical methods implied opportunities as well as problems.

The combination of quantitative and qualitative empirical methods gave unique possibilities to the study:

- The combination strengthened the possibilities for triangulation.
- The combination gave the possibility to chose the level of information: if the issue was specific knowledge on individuals' reactions to changes, the qualitative sources were used; if more overall knowledge as working hours for researchers was the target, the surveys were used.

- The combination gave a possibility to establish a connection of information in specific issues and concepts from different levels: from the individual researcher to the overall management level and thereby possibilities to cross levels.

The combination required knowledge on both empirical methods and access to intellectual and technical resources. In the case study where all interviews were written down, it was essential that the analysis could be done by use of technical support from a computer program (in this case N4-Classic), if this had not been the case the time used on this part of the project would have been much larger or the results poorer. The same argument goes for the survey-analyses; they could not have been performed without proper statistical software (in this case SAS, LISREL).

The requirements of knowledge on both empirical methods implied a *communication problem* to some of the interviewed researchers as well as some of the researchers answering the questionnaire:

- Some argued that surveys in general are not 'scientific' because they focus on means, and information on means could only give simple answers to complicated questions; that we should use qualitative methods to be sure to catch individual differences instead. Information on models based on variances or on latent variables did not change the critical attitude, but information on the qualitative parts of the projects did have an influence in some cases.
- Some argued that the survey studies were not 'scientific', because the questions on attitudes were not 'objective', that they were designed to show differences and structures in mathematical models were not acceptable to all.
- On the other hand some argued that one could not rely on the individuals who were interviewed because they were 'subjective'; that this 'subjectivity' is a core part of doing qualitative interviews in the way they were conducted, were not acceptable to them.

The overall conclusion is that the project gained from the combined strategy.

2. The Danish Research System - with focus on the Public Sector

The total research sector can be divided into a public and a private part, where rules and traditions differ. The line between the public and the private sector is crossed in several ways: e.g., the researchers in both sectors have been educated at public universities, and a number of projects in the public sector are partly private financed. The major research units within the public sector are universities and Government Research Institutes (GRIs). The focus in this report is on these institutions.

After a period of approximately 20 years with a unique managerial system within the Danish university sector, where all researchers, students, and technical personnel had an impact via an election system to different collegial bodies; the system was slightly changed in the beginning of the 1990s, where heads of departments as well as study-directors where given new roles as managers. In the last decade the situation in the government research institutes was also changed. One important change was that the positions structure for researchers at the GRIs were equalised with the position structure at the universities.

During the last five years, a reform in the public research sector has been heavily discussed among politicians as well as among researchers at public institutions. The former government established a research commission, but the commission's proposals were not followed up. After the general election in 2001 the new government announced a reform and in November 2002 four papers on the future system were published: one on universities (1st November), one on government research institutes (29th November), one on the Danish National Research Foundation (22nd November), and one on the public research council system (22nd November).

The first law proposal on the universities was presented the 15th January 2003; it is expected that the law will pass the Danish Parliament during spring 2003. The reform includes managerial changes as well as changes in the study-structure. The largest change is a change of the election system (see section 2.2): the coming heads may be appointed and a new structure with appointed supervisory boards instead of collegial bodies may be introduced at most levels. The proposal includes an interim management by the elected managers until the end of the election period. In February 2003 it was announced that the law proposals on the GRIs would be made in autumn 2003. Because of the uncertainty related to the outcome, elements from the coming reform can therefore only partly be addressed in the next subsections.

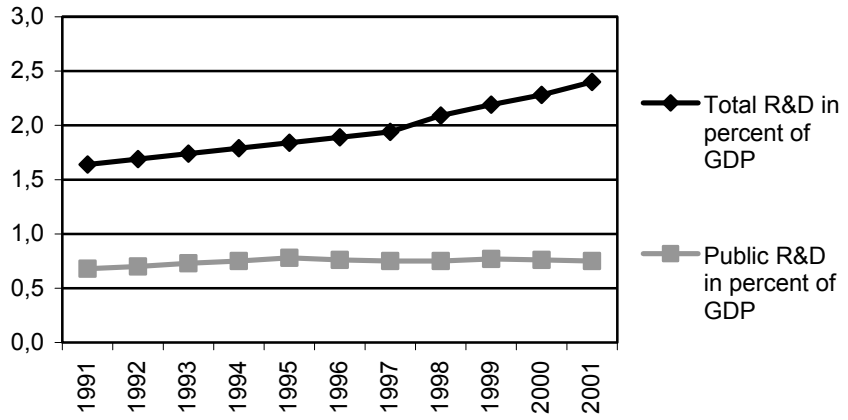
In general the research sector, as with other sectors, receives inputs that are transferred in a (performance) process to output. The expenditures can be regarded as input to the national research sector; this is the focus in section 2.1 where it also is shown that the private sector is significant larger than the public one. In the next two subsections 2.2 and 2.3 a general description of the Danish university sector and the GRIs follows. The employment and promotion structure for public research personnel is then described in section 2.4. In subsection 2.5 a general description of the output from the Danish research sector is to be found.

2.1 Financial Input to the Danish Research Sector

As seen in Figure 2-1 there is a growing trend in the total spending of R&D, but this is mainly due to growth in spending in the private sector, while the public sector only shows minor changes (from 0.68 of GDP in 1991 to 0.78 in 1995 and 0.75 in 2001). This relative stagnation in public spending has activated a growing pressure to the management in the public research sector because new strategies as well as new research problems have to be financed within limited resources in a static management system.

The total R&D expenditures in Denmark were close to 2.5 percent of GNP in 2001, while the public part was only 0.75 percent. Private R&D is dominated by industrial research within the medico/health and IT/communication sectors.

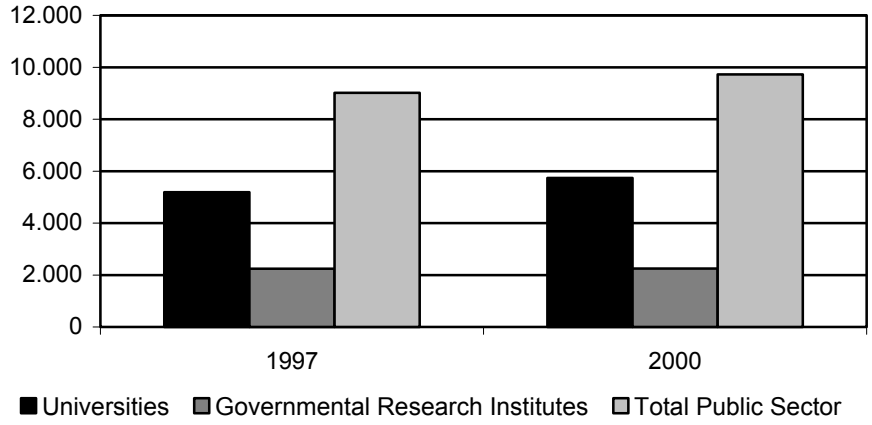
Figure 2-1: Total R&D expenditures and the public R&D expenditures in percent of GNP in Denmark 1991 - 2001



Source: The Danish R&D statistics

The relative positions of the different areas within the public research sector are seen in Figure 2-2; where the research spending at the universities, the government research institutions (GRIs) as well at the total spending in the public sector are seen. Important public sector research institutes beside the universities and the GRIs are museums, archives and non-university hospitals.

Figure 2-2: Total R&D expenditures in the public sector, at universities, and at government research institutes in 1997 and 2000 in Mio. 2000-DKK



Source: The Danish R&D statistics

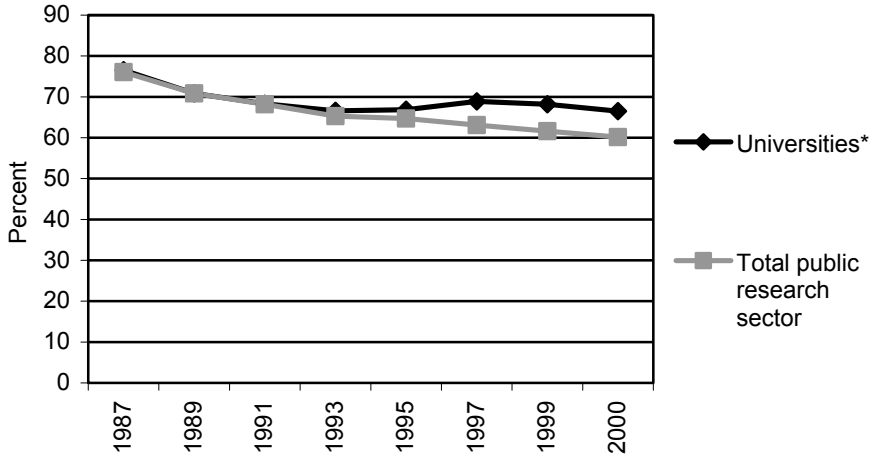
The public research sector is funded by a number of sources, in addition to *the direct funding* or so called '*basic funding'* from the state. Other sources of research funding are from:

- The public sector (besides the direct funding): from research programmes decided by the parliament to research funding decided by ministries or research councils and research project decided by local authorities.
- EU via different RTD-programmes, etc.
- The private sector where the funds are either *contract research*, i.e., research made for the private sector eventually via collaborations projects, or sponsored research.

Direct state funding (basic funding) in 1987 was 76 percent of total expenditures in the public research sector. As seen in Figure 2-3 the percentage of direct funding has been reduced in general in the public sector since then, and a new difference

between the universities and the rest of the public sector research institutions has begun to emerge.

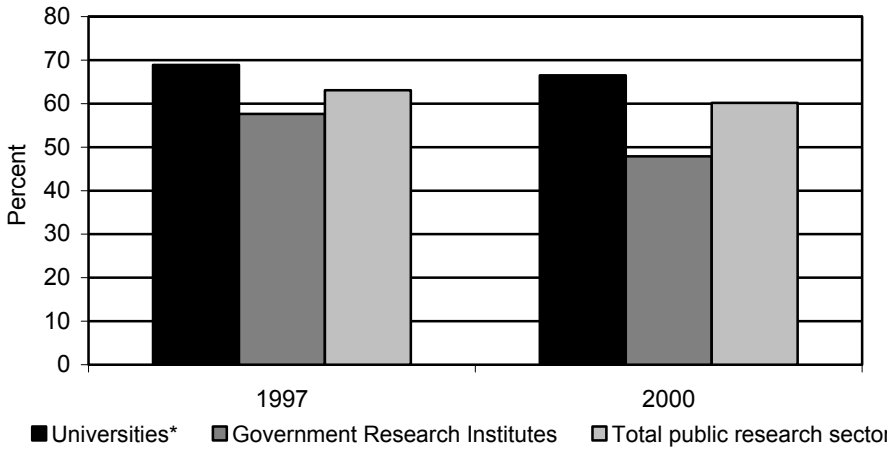
Figure 2-3: Direct state funding (basic funding) of universities* and the total public research sector in percent of total expenditures 1987 - 2000



*A small number of other high level schools is included in the figures for the universities.
Source: The Danish R&D statistics.

In general the government research institutes have had a fallen percentage of basic funding during the last decade, and a number of them are under 50 percent today. The declining basic funding percentage is especially problematic because a number of governmental research-programmes require co-funding from the institutions. The percentage for basic funding for the GRIs is seen together with the total percentage and the percentage for the universities in Figure 2-4.

Figure 2-4: Direct state funding (basic funding) of universities*, government research institutes, and the total public research sector in percent of total expenditures 1997 and 2000



*A small number of other high level schools is included in the figures for the universities.
Source: The Danish R&D statistics.

2.2 The Danish Universities

The main aim of the Danish universities is to conduct research and to offer research-based education at all levels.

Most of the Danish universities are divided into sections, called faculties that consist of a number of departments (the concept faculty have different meanings, the word section is therefore used in this report – see appendix 2). Exceptions are universities that only cover one scientific topic as, e.g., *technical science* and Roskilde University.

Within the last 30 years, the Danish universities have been managed by a number of elected heads, a number of (elected) collegial bodies (councils) corresponding with the head and by a parallel administrative structure at the department level, section level (faculty) and at the overall university level.

The head of the university, called rector, is elected from among and by the associate and full professors for at four-year period. The head of the university works together with the overall university council and the administrative staff at the overall level. The elected head, the rector, is the person in charge of the university i.e. superior to the university director.

The heads of the main scientific sections are elected among and by the associate and full professors for a four-year period. The head of the main scientific sections manage in collaboration with an elected section council called the Faculty Council.

The main scientific sections are divided into departments with elected department heads and elected department councils. Most university studies cross department borders, but they are not necessarily interdisciplinary. Some studies cross sections and a few cross university borders. An elected study-director heads the study-lines.

The election structure has been moderated since the 1970s. Until the beginning of the 1990s most issues where decided by the councils today they have advisory role related to the heads (of departments and sections).

The principle behind the election structure results in effective management in a growing research system because the researchers have incentives to replace ineffective research managers and likely will do so within a four-year period, and because a large number of researchers at the same time can be involved in discussions of development and strategies of new programmes and research areas.

In a system with stagnation or even declining resources an election structure like the Danish one faces problems: if new research areas are to be supported other areas have to be reduced, a reduction implying changes for some of the researchers already employed. The researchers in the areas that are to be reduced would probably fight the reductions and the result is a static system, where groups of researchers would balance each other's influence in order to protect their own areas and interests.

Beside the problems in stagnation periods the Danish election system has been accused for being time consuming and many individual researchers have asked for a management reform including more professional management:

> *"...Problematic management at the department. It is to a great extent hopeless to let academics without knowledge on management manage other academics"*
>
> Researcher at a Danish university, UNI-2000

> *"There is a need for professional management in general. It is difficult to be [an elected] head of department, eventually take unpopular decisions, and then return as an ordinary researcher after four years -*

some will choose not to take the unpopular decisions. This is one reason for the difficulties in finding candidates to the position as head."

Researcher at a Danish university, UNI-2000

On the other hand a number of university researchers have argued that the election-based system is a way to secure the autonomy of the universities, and that the autonomy of the individual researchers is a critical factor in the development of new fields and knowledge areas.

"The classical university with freedom for research, free and open debate is disappearing. Modern 'management types' are an abomination: they have joined too many professional management courses where they have learned to suppress free debate, while asking for discussion and openness. The critical research will receive hard conditions which will harm the debate in society."

Researcher at a Danish university, UNI-2000

A number of researchers as well as managers pointed out when interviewed that the way the managers are selected (elected or appointed) does not matter; what matters is that managers at all levels are regarded as legitimate managers, that they can motivate the researchers, e.g., have managerial skills, and that they have a high level of insight in university matters and traditions. This last qualification points to managers that are (or have been) researchers.

Within the last ten years a number of centres have entered the university structure. Most of the centres have a centre manager or director, and a board. The centres can be parts of larger departments; they can cross department borders or even university borders. The researchers at the centres are often from different scientific fields i.e. the centres are often interdisciplinary. In some cases the researchers working at the centres are employed by a department; in other cases the researchers are employed directly by the centre. Most of the centres depend heavily on external funding.

The universities conduct research as well as they provide education and most university researchers are also university teachers; consequently the universities have to have funding for education besides the research funding mentioned above. The universities in Denmark are funded by the state for providing education; this funding follows the number of students that pass exams (that equals a year of study according to different rules) the full time students do not pay fee, their access depends of prior qualifications; Danish students that pass exams regularly can receive state scholarship (Danish: SU Statens Uddannelsesstøtte). The universities, the research institutions where the PhD students are employed, or

research councils will normally pay fee for the PhD students. Within the last decade the universities have offered a growing number of part time studies (often labelled Master programmes); they are partly paid by fees. All Danish universities are research universities, i.e., all have PhD programmes. To some universities a lack of student within specific areas will imply a lack of funding to specific areas and thereby induce changes.

University of Copenhagen is the largest and oldest university as seen in Table 2-1. Technical University of Denmark, The Royal Veterinary and Agricultural University as well as The Royal Danish School of Pharmacy started as 'one sector high schools (højskoler)' designed to educate technicians to specific sectors; this was a general European trend in the period. They and the later founded business schools have become 'state universities' within the last 20 years.

University of Aarhus and University of Odense were founded as universities divided into sections (faculties), together with University of Copenhagen they are often in Denmark referred to as *the old universities,* where Roskilde University and Aalborg University in a long period were referred to as *the new universities*. At Roskilde as well as in Aalborg the concept *new* covered different structures of departments, which could be interdisciplinary at the *new* universities, in Roskilde this resulted in a structure without sections (faculties) and in Aalborg it resulted in departments crossing the sections. At the *new* universities the teaching methods were radically different from the teaching methods at other universities; they are (more) problem orientated and focus on projects instead on traditional courses.

In 2000/2001 three major changes occurred:

- The new University of Southern Denmark was established by a fusion of University of Odense and a number of minor institutions: The university is characterised by decentralised localisation, i.e., the university has campuses in four cities.
- The new university of education, DPU, was formed by a fusion of one university-organisation and a number of government research institutes. The managerial structure of this university does not follow the general rules for universities; DPU was established with a board and an appointed head.
- The Technical University of Denmark changed statutes and a board as well as the head were appointed.

Table 2-1: The Danish universities

University	Founded	Organisation	Number of students **	R&D personnel 31.12.2000*	Homepage
University of Copenhagen	1479	6 faculties	33.113 (2002)	3.349	www.ku.dk
University of Aarhus	1928	5 faculties	21.588 (2001)	2.424	www.au.dk
University of Southern Denmark***	1998 (1966)	4 faculties	11.991 (2001)	1.296	www.sdu.dk
Roskilde University	1972	No faculties	8.842 (2002)	565	www.ruc.dk
Aalborg University	1974	3 faculties	13.193 (2001)	1.448	www.auc.dk
Technical University of Denmark	1829	No faculties	5.472 (2001)	1.803	www.dtu.dk
The Royal Veterinary and Agricultural University	1858	No faculties	3.114 (2001)	1.622	www.kvl.dk
The Royal Danish School of Pharmacy	1892	No faculties	1.102 (2001)	330	www.dfh.dk
Copenhagen Business School	1917	2 faculties	13.994 (2002)	552	www.cbs.dk
The Aarhus School of Business	1956	2 faculties	4.219 (2000)	209	www.hha.dk
The Danish University of Education	2000	No faculties	-	-	www.dpu.dk
(IT University of Copenhagen****)	(2003)	(No faculties)	-	-	www.it-c.dk

* The Danish R&D statistics.

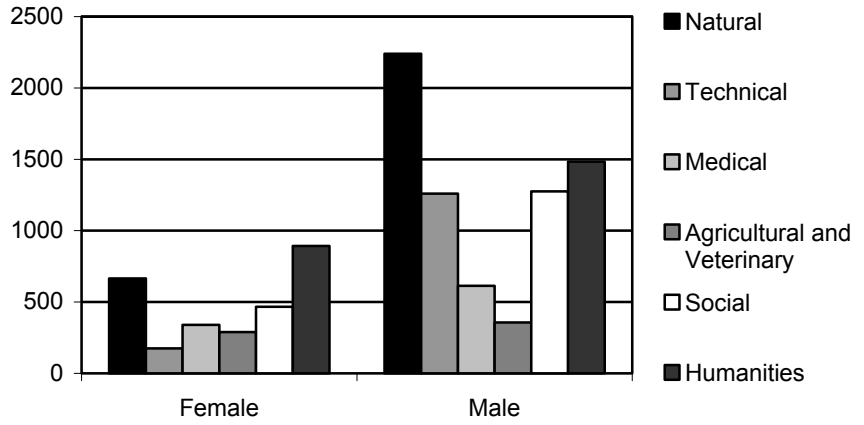
** University homepages and/or annual reports.

*** Founded as a fusion of institutions, where University of Odense founded in 1966 were the largest one.

**** IT-C is today a part of CBS, but according to the reform proposals it will be independent university from 2003 or 2004.

Seen as a total system the Danish universities cover all scientific areas. As seen in Figure 2-5 where the researchers are divided by gender and the six main science field (according to the OECD standards) the largest number of researchers is found in natural science, and the second largest number of researchers is found in humanities. 28 percent of the employed academic researchers are female but as seen in the figure this is not the case within the single main subject: the largest proportion of women is found in agriculture where 45 percent of the employed are women, the smallest proportion is found in technical science with 12 percent.

Figure 2-5: Academic researchers at Danish universities by gender and main science field in 2000, in numbers



Source: The Danish R&D statistics

2.2.1 University Departments

The university departments in Denmark differ in size and traditions. Among the largest is the *Niels Bohr Institute for Astronomy, Physics and Geophysics* (NBIfAFG) at Copenhagen University with approx. 300 persons employed and one of the smallest is the *Department of Classical Archaeology* at Aarhus University with approximately 6 employees.

The large department NBIfAFG was a result of a fusion of four minor departments in 1993. The fusion was based on an international evaluation of physics in the beginning of the 1990s. The four minor departments themselves were also the result of fusions, e.g., the Department of Geophysics was based on a fusion of four small departments that were located in the same place in 1971. A large number of fusions among departments took place in Denmark in the beginning of 1990s: at

the Technical University of Denmark (DTU) and at The Royal Veterinary and Agricultural University (KVL) all minor departments were merged into larger units; at the University of Odense (today a part of University of Southern Denmark) the entire section for humanities was restructured and a matrix organisation was introduced. In 2002 some of the minor departments at the section of humanities at the University of Aarhus were merged.

All departments have collaboration structures related to research that crosses department borders and most (but not all) researchers teach in studies that cross the department lines. The individual researcher faces at least two managers: the study-director and the head of department. This *double manager* situation is a general managerial problem at universities in Denmark.

Even within the same university and the same section (faculties), the actual development of departmental structure differs. Two examples from The Royal Veterinary and Agricultural University (KVL) can show some of the differences. KVL has a number of studies (or study-lines) of which some are closely connected to one subsection within one department and others cross department lines.

The Department of Economics and Natural Resources, (IØSL) KVL was founded in 1990 where four independent departments were merged. Two of the former departments, the Department of *Economics* and the Department of *Forestry,* became subsections within the new large department; the two others formed a new subsection named *Landscape*. All the new subsections within the department were responsible for separate study-lines.

Nearly ten years later two other units were added to the department: the unit of *Learning* and the *Arboretum*. The *Learning unit* is a research subsection within a department responsible for courses at all studies at KVL. At the *Arboretum,* research including experiments is conducted and different courses are offered. Today the department consists of five subsections: Economics, Forestry, Landscape, Learning and Arboretum. The department had approximately 168 employees at R&D activities at the end of 2001.

Department of Dairy and Food Science (MLI), KVL was also based on a fusion of a number of minor departments in the beginning of the 1990s. During the 1990s the education of food technicians began, this study-line is partly based on the success of the dairy technicians that have been educated at KVL since 1921.

From 1992/1993 the basic education line of the food technicians was integrated in the collaboration project with the Technical University of Denmark (DTU) - and today the food technicians can either choose the general line 'food technology' or

specialise in dairy or meat. The latest improvement is the internalisation of the education line as a part of the collaboration project with Swedish Universities.

MLI consists of 7 research units or groups, and a common facilities unit. Researchers from MLI work in the Centre for Advanced Foods Studies (LMC), one of the so-called 'centre without walls' (based on KVL as well as on DTU), as well as working together with researchers from other public research institutions and private firms.

The Food Chemistry Group is a central partner in the EU-project 'BIOPACK'. 20 research projects of different size are listed under the group. Out of these, 5 are focussed on meat and 4 on dairy products.

The Food Fermentation Group (Food Microbiology) was established in 1994 when funding for the fist project was obtained. The group has received funding from The Danish Dairy Board, DANIDA (The Danish International Development Assistance, Danish Foreign Ministry), The FØTEK programme (a Danish research programme) and EU. The group is working together with researchers from other EU countries such as Scotland and Germany.

The Food Technology Group was founded in 1992. The group works with new exploratory, multivariate spec-troscopic methods of observing nature and processes that are non-destructive, rapid and environmentally friendly compared to the traditionally used univariate and slower physico-chemical methods - called FoodMetrics.

The Sensory Science Group was started in the beginning of the 90s by researchers at KVL who were working with sensory science in connection with other research projects. In 1996 the fist professor was connected to the research area and the group was formally founded.

The Dairy Technology Group is working within a long Danish research tradition on milk and cheese. *The Meat Science Group and The Plant Product Group* are newer pendants to it.

As seen three of the research units were either founded or 'upgraded' with a full professor within a short period. This was a result of the primary support from internal funding at KVL followed by a number of grants and other forms of external support.

MLI had approximately 203 employees at R&D activities at the end of 2001.

Where IØSL kept the original structure within the new large department, the original parts of MLI interacted differently and the results were a difference in the organisation of the study-lines: The study-lines of IØSL, including newly developed lines, were kept within the department, whereas the study-lines of MLI cross department as well as university borders.

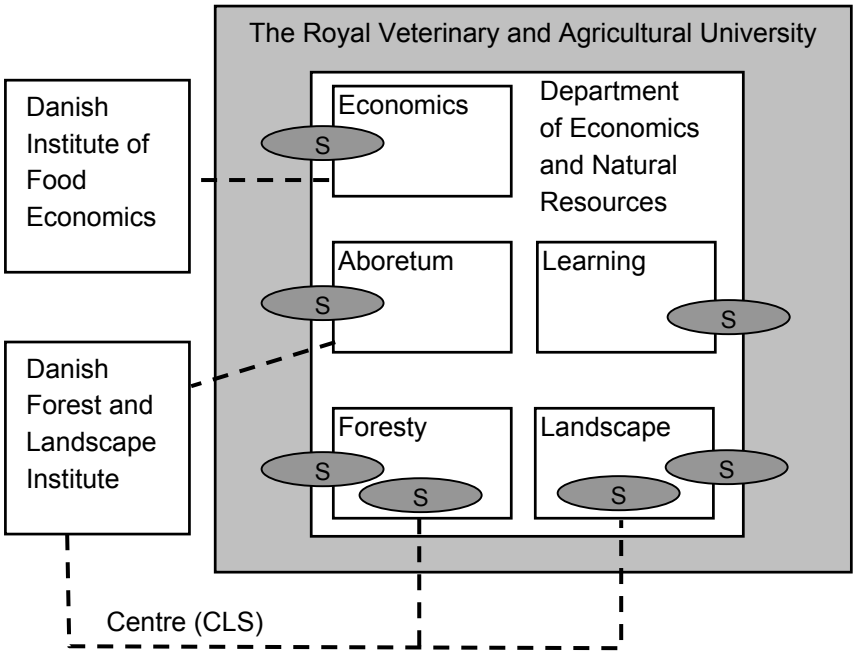
Both departments have close *research connections out of KVL*. The subsections *Forestry* and *Landscape* as well as the *Arboretum* at IØSL share research areas with the government research institute *Danish Forest and Landscape Institute* (FSL). Those common research areas have lead to a number of collaborative research projects between researchers from the subsections and researchers at the GRI in more than ten years.

In 1998 the idea of a major centre crossing the borders of The Royal Veterinary and Agricultural University (KVL) and FSL were introduced, and the *Danish Centre for Forest, Landscape and Planning* (CSL) was founded in 2000. The centre is a virtual centre based on a *'mutual binding cooperation'* between *The Royal Veterinary and Agricultural University*, *Danish Forest and Landscape Institute* and *The Danish Forestry Collage* that entered the cooperation ultimo 1999. In April 2003 a fusion between parts of IØSL and FSL was announced, with the result being a new centre at KVL,

The subsection *Economics* at IØSL shares research areas with the government research institute *Danish Institute of Food Economics,* and a fusion between the two was announced in April 2003, it is still unknown (May 2003) how this will be implemented. In this case no virtual centre was made beforehand, but the two parts have shared a building at KVL since 2001.

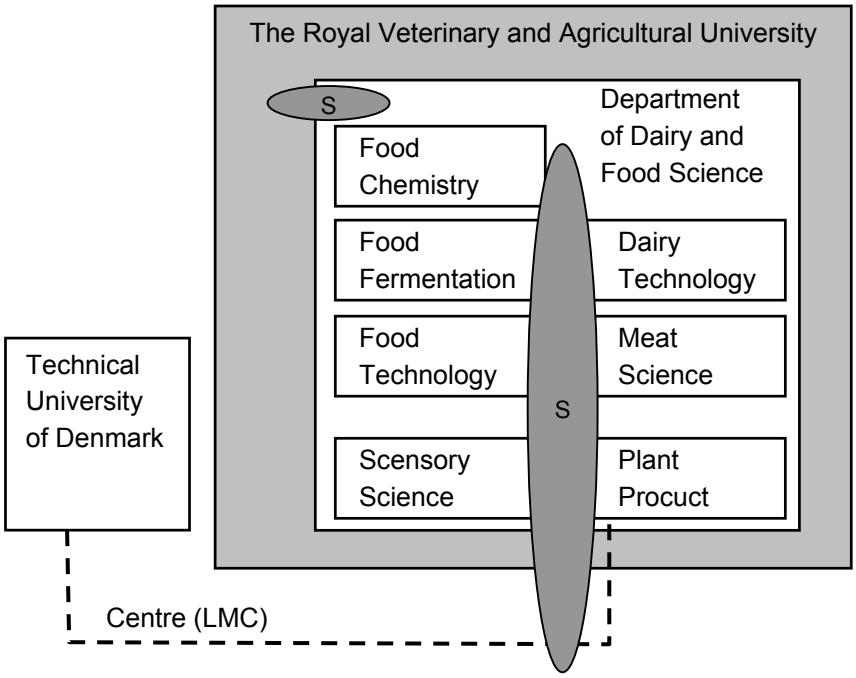
In Figure 2-6 and 2-7 the structures of the two departments IØSL and MLI at KVL in 2002 are seen. Both departments are parts of the overall framework of the Royal Veterinary and Agricultural University (KVL), and both of them offer general courses to students at KVL, showed as 'S' crossing the borders of the department. At IØSL some of the studies are within the subsections, e.g., the subsections have subsection managers as well as study-directors within the sections that consequently covers research as well as studies.

Figure 2-6: The structure of the Department of Economics and Natural Resources, (IØSL) KVL 2002



At MLI the main study involves the different research groups, and it crosses not only the border of the department, but also the border of the university. All the studies have study directors as direct managers. Both departments have a large amount of research project in collaboration with specific centres - at IØSL with GRIs and at MLI with another university.

Figure 2-7: The structure of the Department of Dairy and Food Science (MLI), KVL 2002



Both departments have a large amount of external funding of research projects. This is especially the case for MLI, which has a large degree of external funding of the research projects compared to other departments: At MLI the degree of external funding was 55 percent in 2000, the degree at KVL was 40 percent and for the total Danish university sector the figure was 35 percent. According to the head of the department this has caused a number of managerial problems at MLI:

- The large amount of external funding means that too much time is spend on applications.
- The large amount of external funding gives uncertainty in the planning of research projects.
- The large amount of external funding gives uncertainty among the researchers, and they may or in some cases have to leave MLI, because of lack in employment.

The researchers agree with the head of the department: in a survey 77 percent of the researchers agreed in *'The department is too dependent on external funding'*. The answers at a number of other questions (on attitudes) pointed in the same direction: the researchers disagreed more often in *'Professional competition helps the development of my research environment'* and *'The institution has a clear recruitment policy'* than other researchers at similar departments do. Still 72 percent agreed on *'I have a dream job'*.

The researchers at IØSL and MLI regarded the role as head of department as difficult, in general they approved of their own managers, e.g., head of department, the head of the research groups as well as the overall management; but most of them were critical to the amount of external funding.

While **The Royal Veterinary and Agricultural University (KVL)** can be regarded as a traditional university with regard to research and education, **Roskilde University** (RUC) is different in both respects.

Roskilde University was founded in 1972, a number of years later the first departments were established, including the **Department of Social Sciences.** The main topics of research conducted at the department are:

- The Welfare State and the changes in it.
- Public Administration, Planning and Development.
- Public Sector Economics.
- Technology, innovative resources and processes of change.
- Business Economics with a focus on the recent developments in the theory of the firm.

Some of the researchers are part of national and international research centres that not only crosses the borders of the department but also of RUC:

- CLIF Centre for Local Institutional Research.
- CSS Centre for Service Studies.
- The Federico Caffè Centre.

All researchers participate in one or more research groups, and at the same time they are 'allocated' to a study or a study line. There are no research managers within the research groups, but *contact persons*.

At RUC the students start with two years of basic studies within Humanities, Social Sciences or Natural Science. After the basic study the students can follow B.A. or Master Programmes. The researchers at the department can either be 'allocated' to the basic study for a two-year period, where they will be located together with the

students, or they can teach at one of the study lines that the department is responsible of:

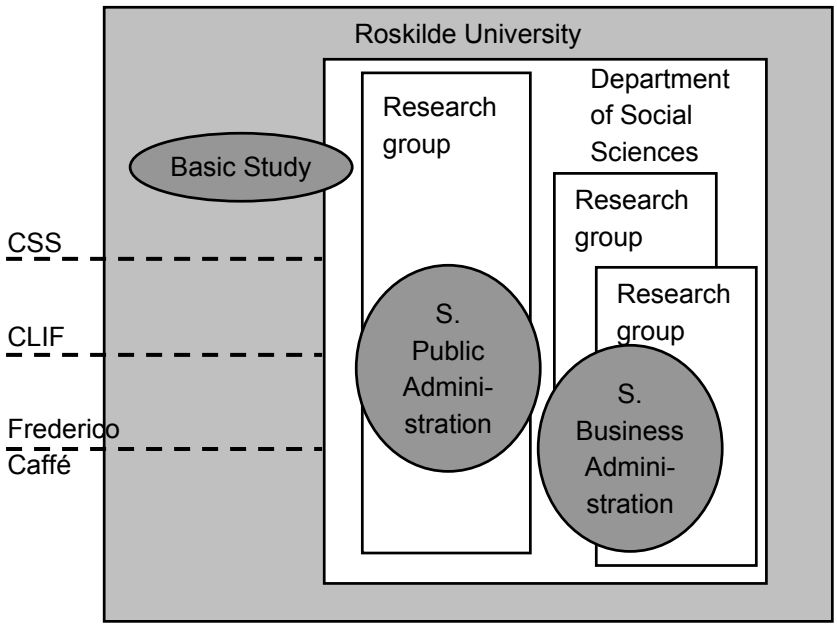
- Public Administration.
- Comparative Welfare studies.
- Public Economics.
- General Business Administration.
- Business Studies

The managerial structure of the department consists of a department head (and a department council) and two study-directors (and two study councils), with the study-lines crossing the research groups.

The department had approximate 118 employees at R&D activities at the end of 2001.

The structure of the department and its *centre*-connections is seen in Figure 2-8

Figure 2-8: The structure of the Department of Social Sciences, Roskilde University 2002



A qualitative study showed (Andersen, P.B, 2002a) that this structure with a number of managers did cause problems in some situations especially in the case where the researchers were allocated to the basic study. This could be due to two reasons: the connections between the student projects at the basic study and the researchers research interests could be weak and that the study-director at the basic study is independent of the department of Social Sciences.

The researchers at the Department of Social Sciences at RUC regarded the role as head of department as difficult, and in general they approved of their own managers, but they were more critical of the overall management of the university.

2.3 The Danish Government Research Institutes

The main aim of the Danish Government Research Institutes (GRIs) is to provide society with research-based information within the GRIs areas. In order to do so, the GRIs have to conduct research within their areas as well as interact with other parts of the research society. All the GRIs are affiliated with a government ministry. Some of the GRIs have been founded within the last ten years while others have a history that goes more than a century back.

A reform was started with a law regulating all Danish GRIs in 1995, followed by a change in regulation of the (job-)positions system in 1997. Until then a number of the GRIs were regulated by specific laws. The new law was designed to cover all state institutions in which a major part of the activities is research. The only exceptions from the law are university institutions, and archives and museums affiliated to the ministry of culture.

As seen in table 2-2, where the GRIs are listed according to the situation in 2002, the GRIs differs in size; the larger ones are divided in sections, programmes and/or departments.

After the election in 2001 the new government announced changes in the GRIs in order to find resources for basic research. After only 3 months work, the Danish Council for Research Policy made a report in the spring 2002. In the autumn 2002 a group of civil servants from a number of ministries made a follow up report, and in November 2002 a new law was announced. Shortly after the election the restructuring of the GRI system began, partly based on declining economic resources. The restructuring involved closure of scientific areas, merging of GRIs, as well as proposal of merging of GRIs into other structures, e.g., universities. The three institutions that were to merge from 1.1.2003 are marked with (f).

In April 2003 the government announced that five of the GRIs should be integrated with the universities, they are marked with (u) in Table 2-2. Others are to be merged with each other; they are marked with (f1) and (f2). *Kort og Matrikelstyrelsen* will be transferred to an unknown unit; and the future for *Danish Building and Urban Research* is still unknown. The *J.F. Kennedy institute* was merged with the *National Eye Clinic for Visually Impaired,* a governmental clinic outside the system of government research institutes.

Table 2-2: The Danish government research institutes in 2002

GRI	Person-nel* R&D	Mainly connected to the Ministry of	Homepage
Institute of Occupational Health	149	Employment	www.ami.dk
Danish Institute for Fisheries Research	255	Food, Agriculture and Fisheries	www.dfu.min.dk
Geological Survey of Denmark and Greenland	275	Environment	www.geus.dk
National Environment Research Institute	153	Environment	www.dmu.dk
Danish Space Research Institute	50	Science, Technology and Innovation	www.dsri.dk
Danish Defence Research Establishment	54	Defence	www.ddre.dk
Risø National Laboratory	852	Science, Technology and Innovation	www.risoe.dk
Kort og Matrikelstyrelsen (f-unknown)	33	Environment	www.kms.dk
Danish Building and Urban Research (Unknown future)	109	Economics and Business Affairs	www.by-og-byg.dk
Danish Institute of Agricultural Sciences (f1)	934 (2000*)	Food, Agriculture and Fisheries	www.agrsci.dk
Danish Forest and Landscape Institute (u)	91	Environment	www.fsl.dk
The Danish Veterinary and Food Administration [The Institute of Food Safety and Nutrition] (f2)	290	Food, Agriculture and Fisheries	www.fdir.dk
Danish Institute of Food Economics (u)	58	Food, Agriculture and Fisheries	www.foi.dk
Danish Pest Infestation Laboratory (f1)	26	Food, Agriculture and Fisheries	www.dpil.dk
Danish Veterinary Laboratory (f2)	368	Food, Agriculture and Fisheries	www.svs.dk
Danish Bilharziasis Laboratory**	31	Foreign Affairs	www.bilharziasis.dk
National Institute of Public Health	48	Interior and Health	www.si-folkesundhed.dk

GRI	Person-nel* R&D	Mainly connected to the Ministry of	Homepage
The J.F.Kennedy Institute	27	Social Affairs	www.kenedy.dk
Statens Serum Institute	349	Interior and Health	www.ssi.dk
Institute of Local Government Studies** (u)	84	-	www.akf.dk
The Danish Institute for Studies in Research and Research Policy (u)	20	Science, Technology and Innovation	www.afsk.au.dk
Copenhagen Peace Research Institute (f)	16	Foreign Affairs	www.copri.dk
Centre for Regional and Tourism Research**	26	Science, Technology and Innovation	www.crt.dk
Centre for Language Technology (u)	23	Science, Technology and Innovation	www.cst.dk
Danish Institute of International Affairs (f)	19	Foreign Affairs	www.dupi.dk
Danish Institute of Border Region Studies** (u)	14	Science, Technology and Innovation	www.ifg.dk
The Danish National Institute of Social Research	101	Social Affairs	www.sfi.dk
Danish Transport Research Institute	39	Transport	www.dtf.dk
Centre for Development Research** (f)	29	Foreign Affairs	www.cdr.dk

*From the Danish R&D statistics (database) figures are from 31.12.2001.
**(Private) Foundation; (f) 1.1.2003 parts of Institute for International Studies (IIS); (f1) and (f2) fusion decided April 2003; (u) integration with university decided April 2003.

With only a few exceptions the GRIs have a board with members appointed by the actual ministry, the ministry of research and members representing the employees. The GRIs are in general headed by a director appointed by the board. After the reform (expected to come in autumn in 2003), exceptions from this should no longer be found.

Qualitative interviews in 1998 with board members as well as directors showed that two main aspects were taken into account when a board at the GRIs should appoint a director: at some GRIs the tradition was that the director should be an internationally well known and respected researcher and that (s)he should have research qualifications similar to the ones required for a full professorship (P) at a Danish University (see section 2.4.1 for qualifications required at the universities; at other GRIs the director should have managerial qualifications (M) similar to the qualifications required from directors at other major public institutions (as one

board member said: as directors at large hospitals). A person with both types of qualifications (PM) would be preferred if possible - and a person with none of the two types would not be appointed.

This gave the matrix of director qualifications as seen in Table 2-3.

Table 2-3: The directors' qualifications at government research institutes

		Management qualifications	
		High	Low
Research qualification	As university professors	PM	P
	Not as university professors	M	(None)

In the same period a survey among researchers was conducted (Kallehauge and Langberg, 1998) that included a number of questions on attitudes. Analyses of the data showed a difference in attitudes among the researchers that could be explained by the directors' qualifications, and the following *hypotheses* were put forward as possible explanation:

- Directors with research experience and qualification as university professors (P and PM) tend to manage differently from others directors (M).
- The director's research qualifications reflects the research environment of the GRI: if the research environment tends to be like the research environment at universities, the appointed director would have to be a respected researcher in order to be a legitimate manager, i.e. (s)he had more often qualifications as a university professor (P and PM).

It was not possible to use the data collected in 1998 to investigate these questions but it was possible to address them in later case studies; no evidence were found to suggest that they are wrong.

The structure and development of two GRIs, Risø and Danish Forest and Landscape Institute will be in focus in the rest of this subsection.

One of the largest GRIs is Risø National Laboratory (Risø). Risø was founded in 1958 to support the civil use of nuclear power and research within nuclear power and technology. However, no nuclear power plant was to be opened in Denmark, and in 2001 the last research reactor (DR3) was closed. Today Risø has a special

responsibility for consolidating the knowledge base on nuclear issues and providing consultancy to governmental authorities within the area.

In the beginning of the1980s it became clear that nuclear power would not be introduced in Denmark and Risø's research profile changed to *Energy and Environment,* in 1989 it was changed to *Energy, Environment and Materials* and new research areas were introduced, among them wind power. In 2000, Risø announced a strategical change to *Wind energy, New materials and Bio production*. The new strategy is based on:

> *"the internationally recognised competences and results of Risø. It is based on the particular possibilities of Risø due to its size, interdisciplinary nature, and external collaborative arrangements. Risø will strengthen its role as the leading Danish research centre within energy technology, materials technology, and on a promising niche within plant biotechnology. The research in radiation protection will be adjusted to the new national requirements".*
>
> www.risoe.dk

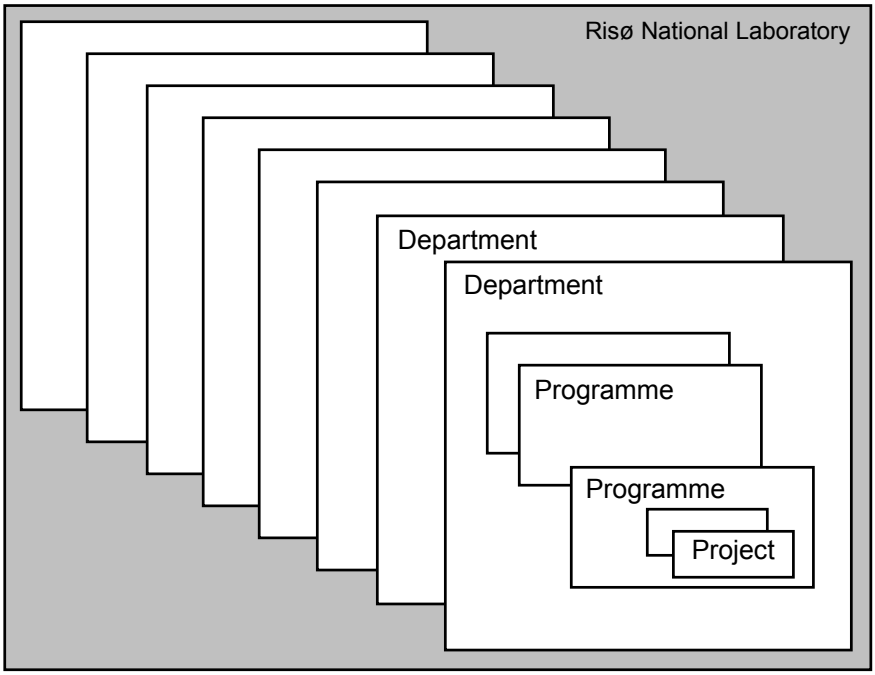
Since its foundation, Risø has been closely related to the rest of the research sector in Denmark as well as in other countries. A number of graduate and PhD students have written their dissertations at Risø and a large number of guest researchers visit Risø every year (Kallehauge, Kindtler and Langberg, 1998). Risø can be regarded as one of the GRIs that follows international sceintific standards similar to the ones at high level universities.

In 2002 Risø was divided into 7 research departments:

- Danish Polymer Centre.
- Materials Research.
- Radiation Research.
- Optics and Fluid Dynamics.
- Plant Research.
- Systems Analysis.
- Wind Energy.

All departments are divided into sections called programmes with a program manager. The different research activities are all parts of programmes, and each activity has a project manager.

Figure 2-9: The management structure of Risø National Laboratory in 2002



The tradition of more informal research collaboration from the beginning of the history of Risø has changed into strategic collaboration with a number of other institutions. Beside the strategic collaboration, Risø collaborates with university departments and other GRIs as well as individual researchers at a number of levels that reflect the managing structure. At department level or programme level the collaborations is mostly with universities, university sections or other GRIs, at project or ad hoc level the collaboration is more often based on individual contacts.

Risø was the first GRI to sign a *contract* (see section 3) with the ministry. This was done in 1993, and *milestones* (see section 3) as well as follow-up on the milestones were integrated in the contract. The strategic processes inside Risø are ongoing processes during each contract period. (Andersen, P.D., 2000).

Beside the collaboration with the rest of the research sector Risø has a number of joint projects with industry and researchers from Risø also perform industrial consultant work. The connection to the industry has been strengthened within the last decade, e.g., chairmen of the board have been well recognised managers from the industrial sector.

The Danish Council for Research Policy suggested in their report from the spring 2002, that Risø should be divided up and transferred to or merged with a number of university departments, but in April 2003 it was decided to keep Risø as one institution.

Danish Forest and Landscape Institute (FSL) is among the mid-size GRIs, and it has a very different story when compared to Risø. FSL was founded as a GRI in 1991 with connection to the ministry of agriculture. The institute is based on a fusion of a number of minor institutions, all dealing with forestry and/or landscape. Some of the minor institutions were (parts of) government research institutions, others were technical institutes providing consultant work (Contract Research and Technology [CRT] organisations approved by the Ministry of Business and Industry) and one part came from the Technical University of Denmark. The different groups of employees came from organisations with different working traditions, with different traditions of funding and different relations to research:

- The university group was the most research-intensive and was mainly funded directly from the state.
- The GRI group was partly research-intensive and was funded directly from the state as well as from state programmes and the private sector.
- The CRT group was mostly financed by consultant work.

FSL was moved from the ministry of Agriculture to the ministry of Environment in 1994. In 1996 the board of FSL and the ministry signed the first *contract* (see section 3), and since then the overall research strategy has been planned and followed up by the contracts (Langberg, 2000).

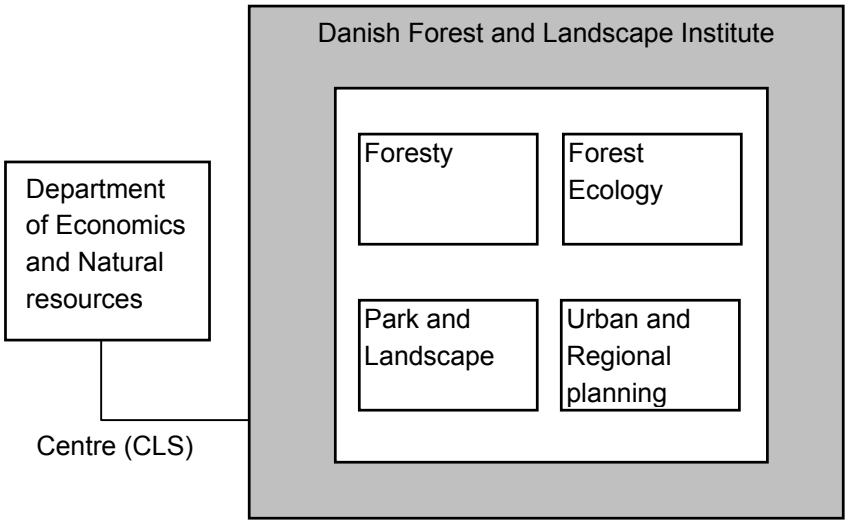
The director of FSL is adjudged professor at The Royal Veterinary and Agricultural University, and is together with the managing director of Risø among the GRI directors that can be classified as '*a director with research qualifications as a full professor*'.

FSL is divided into four departments (2002):

- Department of Forestry.
- Department of Forest Ecology.
- Department of Park and Landscape.
- Department of Urban and Regional Planning.

Each department has a number of research areas. The structure of FSL is seen in Figure 2-10.

Figure 2-10: The structure of Danish Forest and Landscape Institute 2002



The Danish Council for Research Policy suggested in their report from the spring 2002, that FSL should merge with (parts of) the Royal Veterinary and Agricultural University, and it was decided to follow up on this merger in April 2003.

2.4 The Employment and Promotion Structure for Researchers at Danish Universities and Government Research Institutes

Researchers at Danish universities and government research institutes are indirectly employed by the state. As with other state employees, researchers' wages and other issues connected with their employment contract are based on a general main contract between the state and the labour unions, in this case the academic organisation. Where the wage system in general follows the same structures as the wage system for other academics employed by Danish state institutions and organisations (as seen in section 2.4.2), the promotion structure at the universities and the GRIs follows the university traditions (as seen in section 2.4.1).

From a labour market perspective the academic (researcher) have three employment possibilities: the public research sector, the public sector in general and the private sector. The employment has different consequences as seen in Table 2-4.

Table 2-4: Relative difference with regard to wage and other aspects in different form of employments for academics

	Employment as researcher at universities or GRIs	Other public employment	Private employment
Wage	-	-	+
Freedom to decide objects and methods of work	+	-	-
Job security (low position)	-	+	-
Job security (high position)	+	+	-/+

Note: + implies more than general; - implies less than general

Until 1990 the Danish university researchers faced a formal *working norm* called the UFA-norm (U=education; F=research; A=administration) at 40; 50;10 meaning that over a period the individual researcher should teach 40 percent of the time, conduct research 50 percent of the time and do administrative work in the last 10 percent. This norm was removed but is still referred to in discussion of time allocation at universities and indirectly at GRIs. The actual time allocation at Danish universities and GRIs is seen in Table 2-5.

Table 2-5: Time allocation on the job among researchers at Danish universities and governmental research institutes. Percent of total working hours and working hours a week

Activities	University researchers 2000	Researchers at GRIs 1998
Research	45.9 %	48.5 %
Guiding of other researchers	1.6 %	2.8 %
Teaching and guiding of students (incl. PhD students)	30.9 %	3.2 %
Writing applications for funds	3.4 %	6.2 %
Advising, consultant work	1.8 %	14.9 %
Administration and authority work	8.6 %	12.2 %
Other activities incl. personal training	7.8 %	12.2 %
Mean working hours a week	47.2 hours	41.9 hours

2.4.1 The Position and Promotion Structure for Academic Research Personnel at Danish Universities and Government Research Institutes

Today the Danish universities, the Danish Government Research Institutes (GRI) and most of the private non-profit organisations employ their academic research staff according to the same structure. In this structure documented scientific qualifications play an important role. Those scientific qualifications can be: PhD and/or Doctor degree (similar to the German *Doctor Habile*), the number of articles in reviewed journals, patents, etc. The necessary qualifications are different in different scientific areas, e.g., in some scientific fields patents are important and in others monographs are central.

This system is somewhat different from the *tenure-system* known in the USA (American Council on Education et al., 2000). The main difference is that all younger researchers as assistant professors and researchers in Denmark have temporary contracts, and that none of them are entitled to a tenure evaluation.

Since the beginning of the 1990s a larger proportion of the funding has come from other sources than the *direct state funding* (see section 2), 33 percent of the funding today is from these other sources. This lead to a shift in demand for researchers at time-limited contracts at the universities, and a growing group of researchers were employed on short time contracts - at low levels in the position structure. In 1993 an employment structure parallel to the *ordinary employment structure* was introduced: the *supplementary employment structure*, where all contracts were limited to a period and the personnel employed were often focussed on research. Until the 1st. September 2000, all positions as associate professor and full professor were not period limited, while personnel in these categories employed after the 1st. September 2000 may in some (exceptional) cases be employed with period limited contracts, and the supplementary structure was removed. No investigation of the structural change has yet been made.

In 1997 the employment structure at the GRIs changed as a consequence of a new law on GRIs of 1995. Until 1997 the employment structure at the GRIs in most cases was similar to the general structure at other government organisations (ministries, government departments etc.) where personnel employed by the state in general have contracts with no period limits. After 1997 the structure was changed to a structure more similar to the one at the universities. The structure change focussed on the research qualifications, e.g., the research qualifications should be the same at the same level at the GRIs and at the universities, and period limited contracts were introduced at the low levels of positions. While researchers at universities normally teach, researchers at the GRIs normally have advisory and/or monitoring functions (as seen in Table 2-5). All researchers already employed at GRIs were evaluated according to the new rules - and the

ones who didn't have a PhD or equivalent were either offered another job, or transferred to jobs labelled *senior advisor*.

The ordinary employment structure at Danish universities and government research institutions is seen in Table 2-6.

Table 2-6: The ordinary promotion/employment structure at universities and government research institutions in Denmark 2002

Requirements	Positions at universities	Positions at Government Research Institutes
MA or MSc.	Research Assistant *	Research Assistant *
	PhD - student *	PhD - student *
PhD or equivalent**	Assistant professor * Researcher* (Post doc)	Researcher * (Post doc)
PhD or equivalent plus a number of scientific publications Or equivalent qualifications**	Associate professor	Senior researcher
PhD or equivalent plus a number of scientific publications Doctor (like the German Habile) or equivalent qualifications**	Full professor	Research professor*

* All contracts on these levels are period limited (temporary).
** It was not until the beginnings of the 1990s that all scientific areas in Denmark started formal Ph.D. studies; some associate professors and professors might therefore not have a Ph.D. (or Doctor) degree.

Research assistants have temporary contracts limited to two years at one institution. *PhD students* are normally employed with a three-year contract and often evaluated every six months; if they do not perform as expected the contract may be cancelled. The *assistant professors* at the universities and the *researchers* are often employed on a three-year contract that cannot exceed five years; these positions can be labelled *post doc*.

Positions as *associate professor* and *full professor* at Danish universities are all publicly announced and anyone with the proper qualifications can apply. The number of full professors is limited in two ways: the number cannot be expanded by the universities without permission from the ministry, and in some cases the

universities do not announce a specific full professorship because of lack of funds. As seen in Table 2-7 this has caused a relative limited number of full professors. It is also seen that the proportion of full professors differs within the six main science areas (as defined by OECD).

Table 2-7 The proportion of full professors at Danish Universities by science 2000

Science	Proportion of full professors of (full professors, associate professors and assistant professors)	Proportion of full professors of all researchers at Danish universities
Natural science	14.6 %	9.0 %
Technical science	13.6 %	7.6 %
Medical science	18.9 %	11.7 %
Agricultural and Veterinary science	16.9 %	7.9 %
Social science	20.6 %	13.5 %
Humanities	12.6 %	9.2 %
All	15.5 %	9.8 %

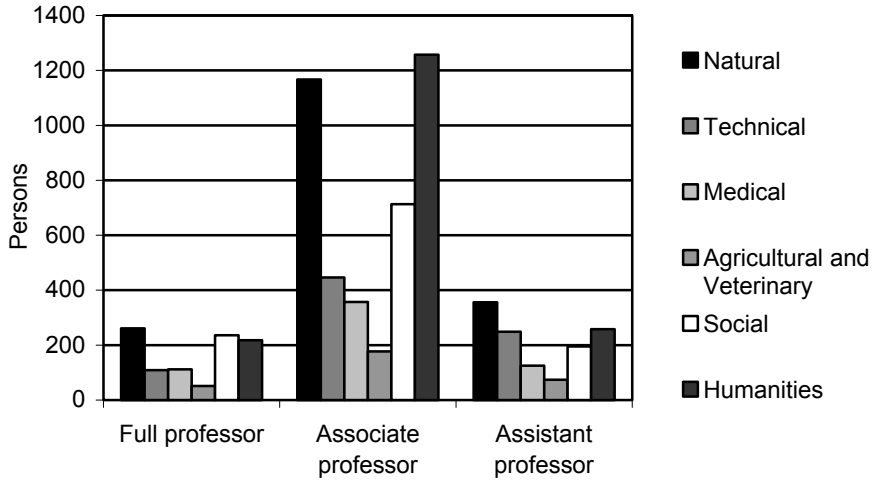
Source: The Danish R&D statistic.

A foreign researcher at a Danish university commented the limited numbers of professors with:

> *"Full Professor title must be conferred to those people who deserve it! The title "Associate Professor" is most humiliating after a certain maturity, a maturity that has been recognised by the community in your area of research (by the quotations you receive for your work, by the external, international research grants you obtain, by the international research projects you coordinated in the past and have been coordinating currently, by your publications - books, papers-etc. etc.!!!!!!"*
>
> Foreign researcher at a Danish university, UNI-2000

The actual number of university researchers is seen in Figure 2-11 and 2-12

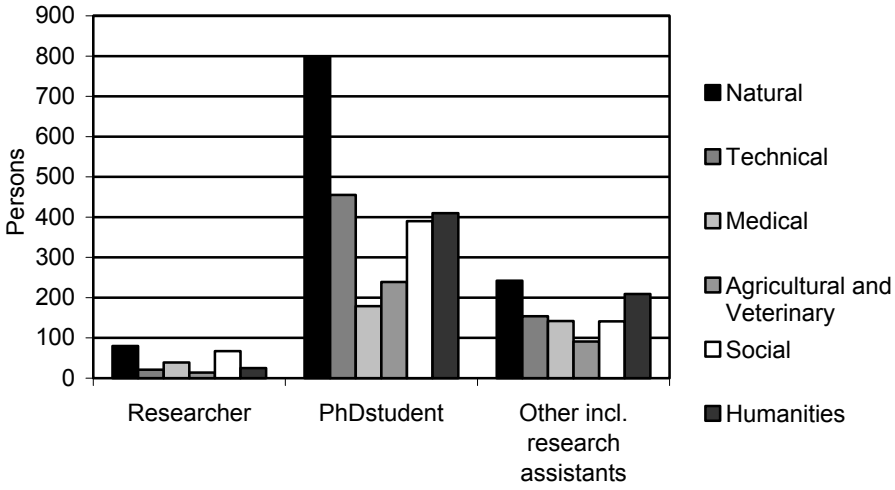
Figure 2-11: Researchers at different professor levels at Danish universities, by science 2000



Source: The Danish R&D statistics.

The largest group among other researchers are the PhD-students as seen in Figure 2-12.

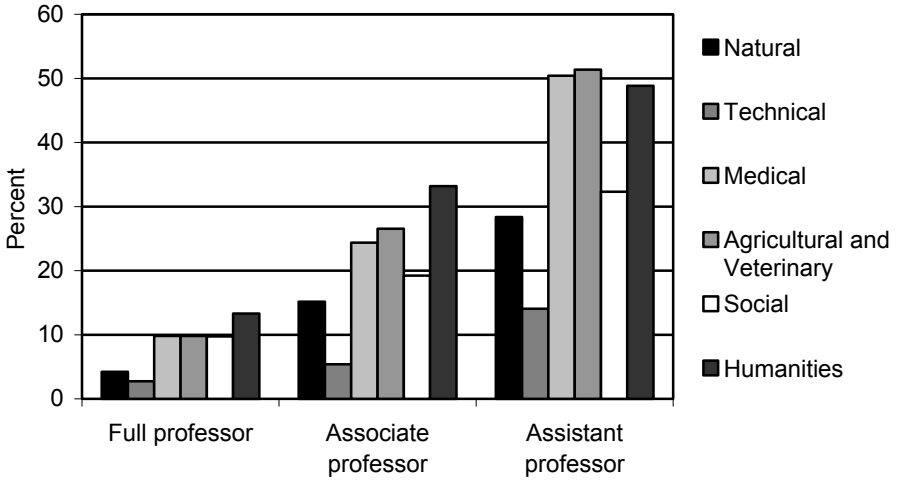
Figure 2-12: Researchers at Danish universities in other positions than professors, by science 2000



Source: The Danish R&D statistics.

The overall percentage of female researchers at Danish universities was 28 percent in 2000. The percentage differs according to science and position as seen in Figure 2-13 only 8 percent of the full professors and 22 percent of the associate professors are women.

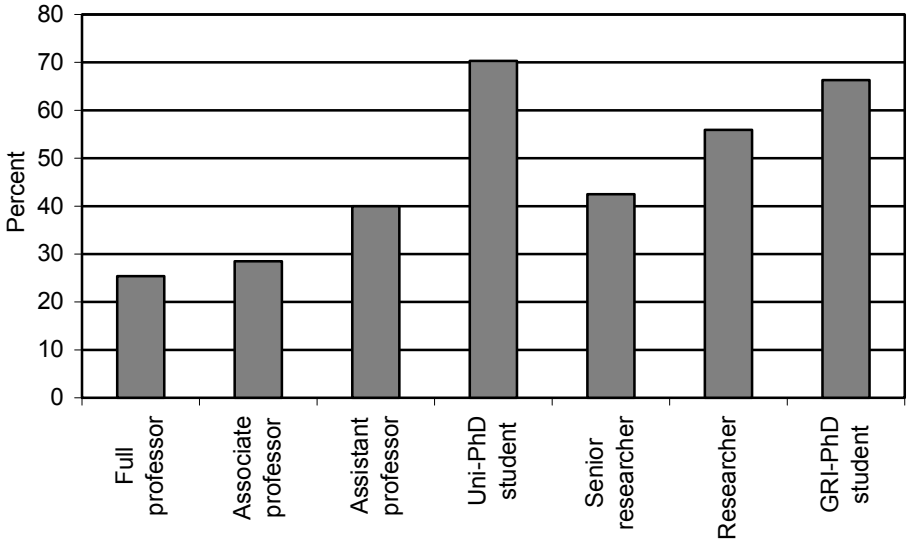
Figure 2-13: The percentage of female professors by science at Danish universities in 2000



The full professors as well as some associate professors act like research managers at a number of departments and centres, and consequently they spend less time on own research than others as seen in Figure 2-14.

Surprisingly, it was found that the researchers at the GRIs used relatively more time on research than their university counterparts: if the research percentage for senior researchers is compared to the one for associate professors and the percentage for researchers is compared to the one for assistant professors this is seen to be the case; but the PhD students at the universities used relatively more time on research that the PhD student at the GRIs.

Figure 2-14: Time allocated to research in percent of total working hours at Danish universities (2000) and GRIs (1998)



2.4.2 The Salary Structure at Danish Universities and Government Research Institutes

Wages at the public research institutes are determined by *a main contract* agreed by the academic organisations and the government. This main contract system is the overall system in Denmark (and other Scandinavian countries): in principle the labour unions (in this case: the academic organisation) and the organisation of employers (in this case: the government) will make an agreement about wages, number of working hours a week, etc. The organisations and the persons covered by the main contract have to follow it (regardless of union membership).

The main contract of academic personnel in the public sector was changed in 1998. All employed in 1998 and later have to follow the *new wage system*, people employed before 1998 can choose to stay at the *old wage system*.

The old wage system is stiff; the salary is solely determined by education, seniority (a scale with 16 steps) and special (automatically given) extras depending on, e.g., job rotation and formal position.

The new wage system is more flexible, still depending on education and seniority (a scale with 8 steps) but with a number of extras and bonuses. Those extras and bonuses are often negotiated by a locally elected representative of the union and

the management within an *economic frame*. This frame can be very narrow, and as a consequence there can be very limited room for bonuses at some institutions.

The new wage system is supplemented by a system of *wages by results* in the public sector; this implies that there is a possibility of bonus if a manager or a group of employees manage to reach specific results.

Risø is one of the GRIs that adopted the system of *wages by results* at an early stage.

The non-profit private research organisations in Denmark will normally follow the rules of the state when they make contracts with individual researchers.

Because of the system of main contract a number of researchers are not aware of how the contracts are made, and they don't care because they regard their influence on the salary as very limited. But many of them bear the opinion that they would be better off if they were privately employed.

In short: if you have information for a researcher on position and number of years since graduation (=that normally follows the seniority) you will have information on the wages of that researcher, this is the reason for not including information on wage in the questionnaires that were conducted within the project.

2.5 Output from the Danish Research Sector

The different public research institutes have different outputs or outcomes. Unlike other counties, e.g., Norway, no central information is collected on the outcomes from the public research institutes, but information can be found at the department level in most cases in annual reports etc.

All the Danish GRIs are evaluated regularly and a number of university departments and/or scientific areas have gone through international evaluation within the last decade. When an institution or area is evaluated a registration and valuation of the research outcome is performed.

The information on output differs from university to university and in some cases from section to section within the university, and it has until recently been rather uncertain.

At the GRIs, information on output in general have been more accurate partly because of management systems with milestones etc. (see section 3) and partly

because a large number of the research projects conducted at the GRIs are financed by external grants. Additionally, the GRIs have different registration systems.

It is hard to calculate the *value* of the total output from a research institution because research enters into different areas of the society in different ways. Some research is presented to students and enters via the graduates into other sectors, some research is published and used by others that have read the articles or books, some research is presented at conferences, and some research is patented and later used in the industry. The use of the research might be within a short period after the presentation/publishing, or many years after. Unlike material products, research and other knowledge products can be used several times. Research is often co-produced with other forms of output: e.g., education and advisory work. Consequently, a number of research institutions will prefer to publish indicators of research together with other indicators.

Universities and university departments will normally record scientific publications and measure for the amount of teaching in one way or another in order to indicate the production; examples of such indicators are seen in Table 2-8. As seen the list does not include the number of researchers at different levels, and it is therefore not possible to compare the productivity of the researchers at KVL in general and the researchers at IØSL, KVL if the productivity is to be measured as output pr. researcher in some way (see section 3).

Table 2-8: Indicators on research and teaching output at *The Royal Veterinary and Agricultural University* (KVL) and at *Department of Economics and Natural Resources* (IØSL, KVL) in 1999

Outcome in numbers	KVL	IØSL, KVL
Scientific monographs	37	9
International articles with referee	438	39
Other scientific articles	74	41
Conference presentations published in proceedings	182	32
Books, reports, etc.	75	44
Other articles in journals, newspapers etc.	115	55
Number of PhD and Doctoral degrees	71	10.2
Number of *STÅ* = Exams passed that equals a year of study	1958	413.38

Source: Langberg, 2000

Government Research Institutes (GRI) will normally report their scientific production as well as other forms of production dependent on their statutes. Some GRIs have had contracts (see section 4) for a number of years and they might report indicators of production together with the *'milestones'* that were agreed on when the contract was signed, an example of this is seen in Table 2-9.

Table 2-9: Indicators on output and 'milestones' from Danish Forest and Landscape Institute (FSL) in 1999

	Output in 1999	Annual 'milestone'-figure for the period 1996-1999 according to the contract*
Scientific publications		
International publications with peer review	35	23
Other international publications	63	19
Danish publications with peer review	16	5
Other Danish scientific publications	55	9
Other forms of knowledge presentation/ transformation outside FSL		
Videnblade (a Danish newsletter from FSL on different issues)	141	110
Advisory work in month for the ministry	20	13
Advisory work in month for other public authorities	13	9
Teaching and censoring in days	63	60

* See section 3.
Source: Langberg, 2000.

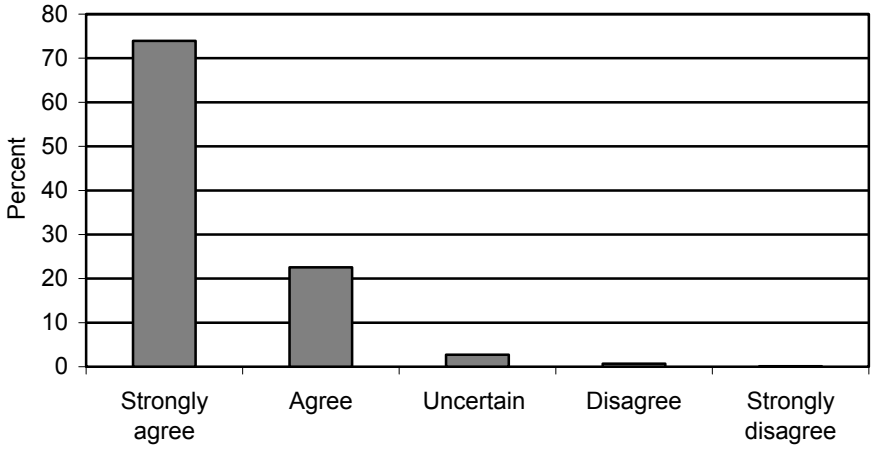
3. Actual Research Management in the Danish Public Research Sector - and some of the Models behind it

The overall tendency in Denmark as in other countries with a large public sector is that the public institutions face pressure from the state to change for several reasons, where one issue is a cut in governmental expenditures, allowing other areas to growth or tax to be reduced. The universities are, as the government research institutes, state institutions in Denmark and consequently their budgets are parts of the total state budget and as such discussed regularly in the parliament. Being a part of the government sector, management of universities and GRIs is affected by managerial changes in the governmental sector in general. In the government sector, the actual management has changed along with the development of new models for management; one important trend in the discussion was the reformulating of management models from the private sector, a reformulation that often has been labelled *New Public Management.* The ministry of Finance has published a number of initiatives and reports on managerial issues to support changes at local levels (Økonomistyrelsen, 1998; Finansministeriet, 1999) The Danish governmental sector has a decentralised management structure meaning that changes have to be initiated and implemented at the local levels; one example of an initiative is the support of quality management prizes in the late 90s. Consequently, a number of Danish government research institutes were involved in discussions and implementations of different forms of quality management in this period. Along with this general discussion in the governmental sector, the discussion of management at the universities has been more intensive, a discussion often focussed on the election system that is described in section 2. Some university managers have joined the discussion in newspapers as well as at conferences, etc. Unsurprisingly, they often support the election system as such, although they point to a number of problems (Wenneberg, 2000, 2002; Andersen, P.B, 2002b). The changes in the management of the universities announced by the ministry of Research in 2002 and followed up in the spring 2003 can partly bee seen reflecting the overall changes in the government sector.

Research can be *interest* as well as *market* driven, where *interests driven research* is research driven by the *researchers interests* and the *market driven research* is driven by firms, politicians or others focus on a specific subject where they use the market mechanism to support the research, e.g., contracts with the research institutes or researchers on specific research projects. It is often assumed that interest driven research is more *basic* than market driven, and it is often assumed that university research is more interest driven that research conducted other places. Consequently, one of the criticisms of the announced changes at the

universities argues that the university research is (solely) 'interest driven' and that an appointed research manager with a board including external members in the *best case* will make no difference and in the *worst case* will destroy the research environment, because of 'external managers' lack of knowledge on research (Lauridsen, 2002). But as seen in Figure 3-1, researchers at the GRIs that for years have conducted 'interest driven' as well as 'market driven' research in general have an interest in the context of their work. Analyses showed that the level of interest was closely linked to the level of satisfaction with the job and that this (research) interest might have been the initial reason for the researchers to be employed at the specific institutions, and at the Danish universities a number of researchers can be found that actually do perform research that partly is market driven.

Figure 3-1: Answers to *I'm very interested in the content of my work* from researchers at Danish GRIs in 1998



The market demand for research, development, and consultancy, seen from the point of the public research institutions, goes from demand for laboratory tests, like tests for viruses among animals, to large collaboration projects like development of wind power plants. This gives the managers of the public research institutions a number of opportunities for financing the research, opportunities that are followed by a number of problems. Often the research interest and the actual market demand for research are congruent, and when this is not the case the conflict has to be addressed by the managers. The market demand consists of different components: demand from the private sector as well as from the public sector for

tests and collaborations-projects, etc., and demand from the public sector on research within a specific area, e.g., environment or energy.

The public institutions are mainly paid by taxes, and most managers within the public sector do not face a market with simultaneous (demand-)information on prices and quantities, but they face a demand for services together with a fixed budget. However managers at public research institutions face a market with simultaneous (demand-)information on prices and quantities as well as a demand for services together with a fixed budget. Consequently the management in the public research sector face at least two *bottom lines*: a bottom line on the total accounts and a 'bottom line' for research (the part mainly based on public money, e.g., taxes). The 'bottom line' for research is often controlled by the board (and government) via systems, e.g., evaluation or benchmarking. This 'bottom line' for research is also of interest for the researchers employed as well as for researchers that might be interested in employment at the institution in the future.

Research can be regarded as production of knowledge as well as knowledge transformation; one important perspective on research performance function could therefore be the perspective of Knowledge Management (KM) as seen in section 3.1. Public research management in Denmark as well as other places has to face its dependence on the rest of the public sector as well as the private sector. This dependence on funds and knowledge information and the general interaction with the rest of societies dependence is in focus in the Triple Helix concept; this concept is also broadly addressed in section 3.1.

In connection with ReMaC as well as with other projects at AFSK a number of managers were interviewed, among those managers at *Risø* and the *Danish Forest and Landscape Institute.* They were among other issues interviewed about the use of Total Quality Management (TQM) and the later Excellence Model, results of this is presented in section 3.2.

Within the last decade, the ideas of contracts and milestones have been implemented in the public sector in general and they were also introduced in the research sector. These managerial tools are presented in section 3.3 together with benchmarking of research that has been discussed in some years in Denmark.

In section 3.4 some conclusive remarks on the actual research management are made.

3.1 Research and Knowledge Management

Knowledge can be regarded as explicit as well as tacit knowledge. Where explicit knowledge is knowledge that the holder of the knowledge is aware of, tacit knowledge can be thought of as knowledge that the holder of the knowledge possesses or even uses without notice. The distinction between the two forms is not clear, it can be argued that there is a continuum between the two (Howells, 2002) as well as it can be argued that the two types are mutually complementary and only the explicit knowledge can be formally measured.

Knowledge management can be seen from a number of perspectives, some will argue that the core of knowledge management is sharing information, and this information will often be known, explicit knowledge, i.e., the focus might be on ICT-systems, e.g., how all employees can be introduced to different ICT software and how a common ICT-base can be established.

In this section the focus is on the internal knowledge flow, knowledge exchange, and the growth of the knowledge base within an organisation regardless of whether the knowledge is tacit or explicit. The framework is widened to a number of sub organisations within a larger organisation as a university or a GRI.

In general, knowledge can be embedded in single individuals, in organisations, and different forms of medias incl. different forms of technology. The knowledge of an organisation consists of knowledge embedded in the single individuals as well as knowledge embedded in the different structures or rules within the organisation. A key issue for the knowledge management in organisations is the *transformation of knowledge* from one individual to others, from the organisational *structure* to the individual, from individual to the *structure* in such a form that the knowledge is available or embedded in a number of processes performed at different places in the organisation. If this transformation process is systematically supported, the knowledge base of the organisation will, according to Nonaka et al. (1998), grow.

Nonaka et al. presents a model of knowledge transmission that can be addressed to research environments based on fours modes:

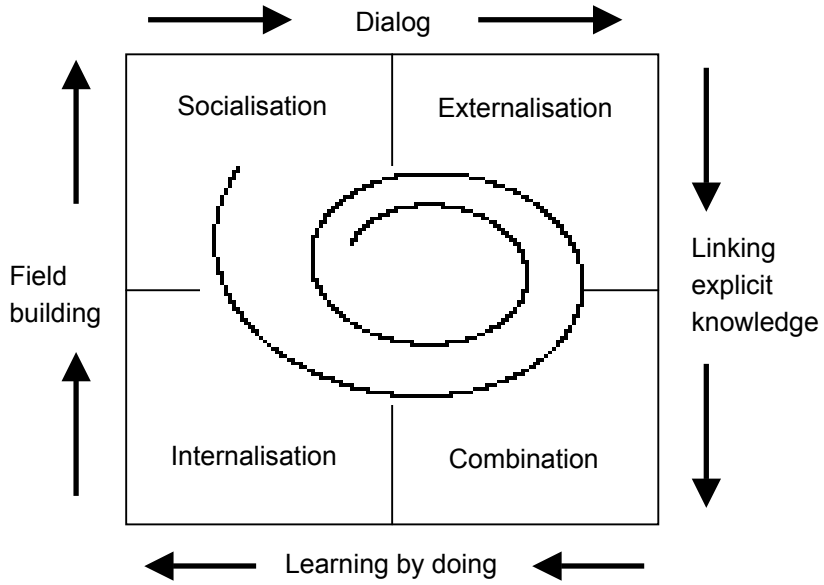
- **Socialisation**: from individual tacit knowledge to group tacit knowledge.
- **Externalisation**: from tacit knowledge to explicit knowledge.
- **Combination**: from separate explicit knowledge to systemic explicit knowledge.
- **Internalisation**: from explicit knowledge to tacit knowledge.

The four modes can be seen as the background for the knowledge spiral that may be started with a *socialisation process* where tacit knowledge is exchanged

between the group members with the result that their attitudes tend to converge. The tacit knowledge can be enlightened by *dialog,* where tacit knowledge is made explicit, i.e., an *externalisation process.* The externalisation process is the base for the *linking with explicit knowledge* from other individuals or other organisations; a link that is the fundament for the *combination process*, where explicit knowledge of different kind are combined. This new combined knowledge is then transformed into internalised tacit knowledge by *learning by doing,* an *internalisation process*, where *field building* supports the knowledge transformation in the *socialisation process*. The circular transmission movement increases the knowledge stock in each tournament.

A managerial support of this form of knowledge exchange will result in a larger knowledge base for each individual and a larger knowledge base in the organisation, and this will have a direct impact on the performance function. A figure inspired by Nonaka et al. (1998) is seen in Figure 3-2.

Figure 3-2: The Knowledge Spiral



It has been shown (Jacobsen et al. 2001; Graversen et al. 2002; Morris 2002; Kalpazidou Schmidt 2002) that the internal communication at university departments, centres, networks, and other units is essential for the level and quality of research projects. Among other elements, internal communication

provides the researcher with important feedback to preliminary results as well as it provides questions and solutions to specific problems.

It can be argued that a support of knowledge exchange will induce a minor loss for the organisation when an individual employee leaves the organisation, because a large amount of this individual's knowledge has been transformed to collective knowledge in the organisation while the individual was working there. The individual leaving the organisation has received knowledge while being there, and the human capital that the individual possesses has grown. The overall result might therefore be that society's amount of knowledge or human capital has grown and that this will support overall economic growth in the long run (Langberg and Graversen, 2001). A consequence of this argument is that mobility of knowledge workers as researchers between different places of work and between different positions may cause growth in society. But the argument can be turned around: if there is a lack of knowledge management, if the knowledge worker just adds knowledge to his or her human capital without possibilities of using the knowledge in the next job in a productive way, or if the internalised knowledge is outdated (or even wrong) the mobility will result in a decrease in the quality of total knowledge base available for performance in the economy. Incentives supporting voluntary mobility combined with networks (to former places of work) are likely to increase the knowledge base and thereby have a positive effect on the performance function; where forced mobility (e.g., induced by the political level as time limited contracts for researchers) may cause a break down in the performance function.

The Knowledge Spiral Model focuses on several processes and combines the development of both tacit and explicit knowledge in a way that fits the description of dynamic and innovative research environments found by Graversen et al. (2002):

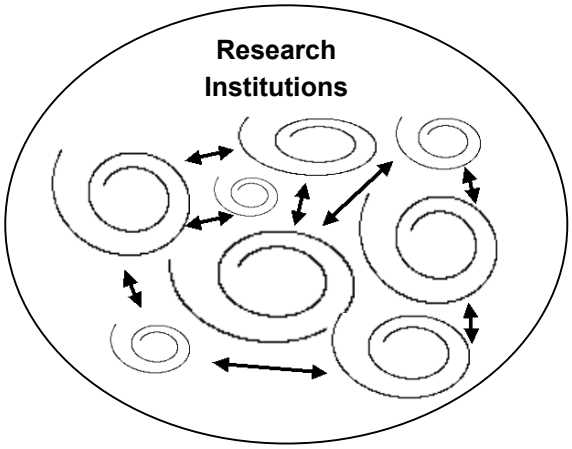
- Dynamic research managers often focus on informal ways to establish knowledge flow as 'coffee tables' areas, where researchers meet when they collect their coffee or the placement of post boxes in a central room, etc., activities that can be regarded as a active support to the informal *socialisation process*.
- Formal meetings or workshops within specific time intervals where research and/or problems are presented, are present as dynamic units; this can be regarded as a support to the *socialisation process* as well as the *dialog* between the researchers. This meeting follows a long university tradition.
- The ongoing process of *combining* own research with other research and knowledge that are presented as papers on conferences, published in articles or books, is regarded as a central part of the research process at

dynamic units that focus on presenting research results to the external world.

- The experiments and the different learning activities of the university includes in a number of cases *learning by doing activities,* where students and guest researchers are invited to join the experiments.
- The training of Ph.D.-students in dynamic units includes transformation and combination of explicit knowledge documented by the dissertation and papers as well as it transforms and internalises tacit knowledge.
- The managers often pointed to their experience from other research environments when they explained why they supported a specific initiative.
- The environments had a relatively large mobility among (young) researchers and managers were involved in networks supporting mobility, still managers were focussed on job security.

Research institutions such as universities and GRIs consist of a number of research environments with minor and larger knowledge spirals that interact with each other as seen in Figure 3-3.

Figure 3-3: Knowledge spirals and their interactions within research institutions as universities and GRIs



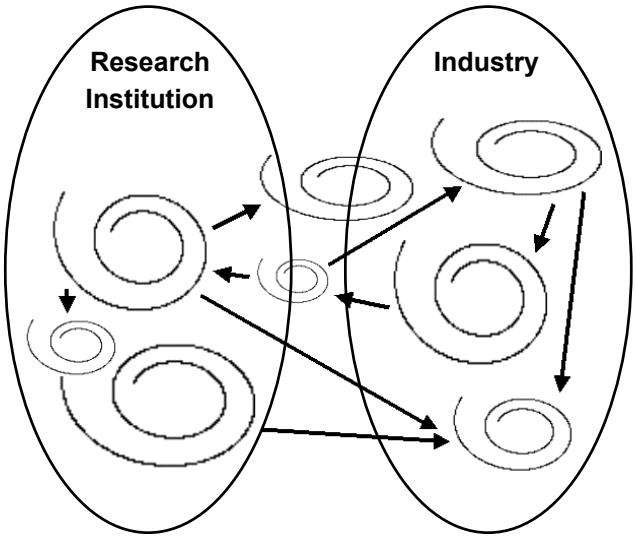
As mentioned above, collaboration and mobility are seen as effective ways of distribution of scientific knowledge within the research sector as well as out of the sector. Where collaboration or co-operation involves exchange and transformation of knowledge without changes in the employment status etc. for the researcher,

mobility from one job to another among researchers implies a change of the knowledge base focussed on knowledge embedded in the individual. In subsection 3.1.1 management in a system consisting of interaction between the research sector, the private (production) sector, and the governmental sector, often labelled the Triple Helix is described. In the following two subsections, 3.1.2 and 3.1.3, the attitudes and factual collaboration and mobility in the Danish research sector is described.

3.1.1 Management in a Triple Helix Context

It is widely recognised that public research is important to the private sector. This relation between the private sector and the public research sector is often presented as a one-way relation where knowledge embedded in individuals educated at universities, or research results from universities and other research institutes, are introduced into the private sector. But networks and direct collaboration between university environments and private firms can change the knowledge flow in such a way that knowledge is transformed and carried from the industry to the university. This could be traditional feedback on research ideas but it could also be information on market behaviour or possible research ideas based on demand for knowledge. In those cases the knowledge spiral of organisations could consist of knowledge spirals of networks - networks between industry and universities that supplement the internal collaboration structures. This picture is seen in Figure 3-4.

Figure 3-4: Knowledge spirals in research institutions, in industry, in networks between research institutions and industry and their interactions

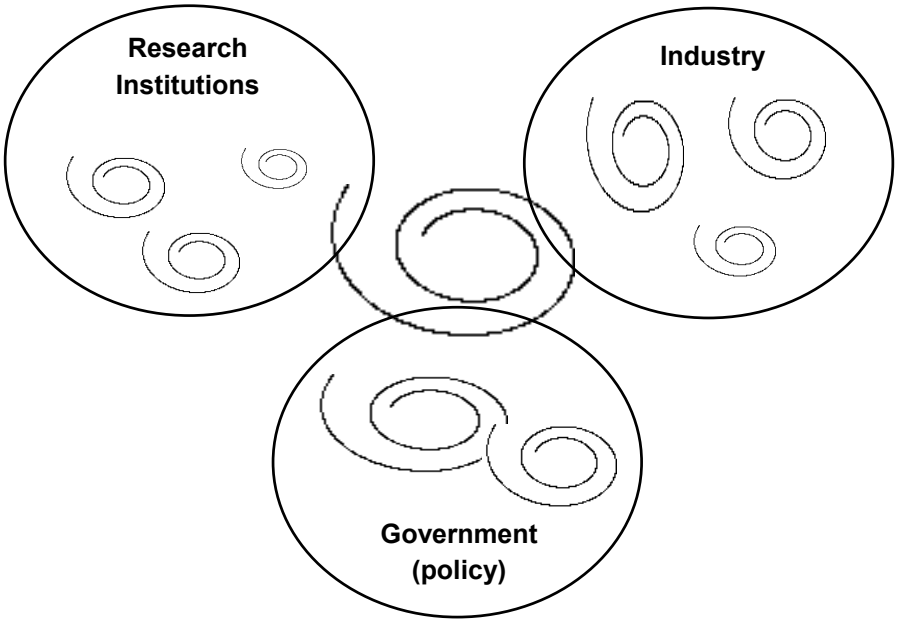


The Triple Helix as presented by Leydesdorff and Etzkowitz (2001), denotes the relationship of university, industry and government and the internal transformation of knowledge in any form within each of these spheres. The picture is inspired by a biological triple helix. Within the Triple Helix concept it is assumed that synergy between the three parts arises and that development of the economy, e.g., economic growth will be the result. The Triple Helix is a model of innovation that differs from other models where focus is on research and industry by declaring "governance" as an integrated part.

The key issue in the function of the Triple Helix is the knowledge flow between the three entities: the research system (in universities and government research institutes), the political system (government) and the private sector (industry) This flow is based on knowledge within the three entities, i.e., knowledge produced as well as knowledge circulated within the entities.

If the third part of the Triple Helix, the Government (or policy level) is added to picture shown in Figure 3-4, Figure 3-5 arises.

Figure 3-5: Knowledge spirals and the Triple Helix



Since 1996, four Triple Helix conferences have been arranged. At the latest conference held in Copenhagen & Lund in 2002, one of the conclusions at the ending session was that a fourth item might be added to the concept: the perspective of the public.

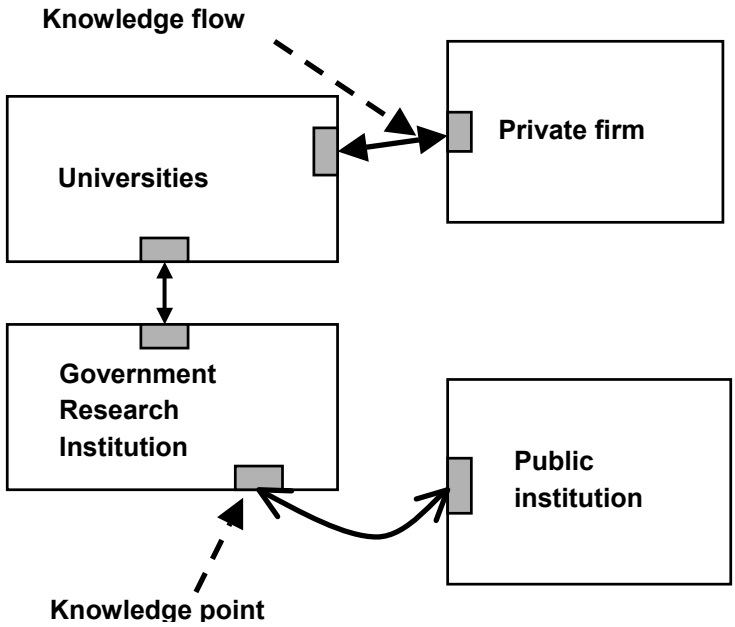
Nearly all of the 'dynamic managers' interviewed in 2002 (Graversen et. al, 2002) acted within a Triple Helix context: they were aware of the importance of knowledge exchange within their own organisation, they were aware of the political level, many of them were or had been active in forming the research policy within their area, and most of them had excellent relations to the private (industrial) sector. But one problem often faced by public research managers who act within the Triple Helix context is that they have to deal with limited basic funds (the part of the funds that are provided by the state) because the growth of the research environment has been based on external funding (Langberg, 2002d).

The insight that the Triple Helix concept provides is that the knowledge network crossing the organisational borders of three entities can support growth - but how this kind of network can be supported and what concrete initiatives research managers can take are more or less open. The loose and to some extent anarchic structure of the Triple Helix is a challenge to the research managers, especially newly appointed managers and managers of minor departments. This could lead to the following conjectures:

- That only large research organisations can enter directly into the Triple Helix set-up.
- That research managers need to have direct contacts with managers in the private sector as well as the political system.
- That a number of (minor) research environments don't have access to the Triple Helix set-up unless supported in some way or another.

In order to support minor local research units with external collaboration projects, universities and government research institutes have provided administrative routines and information offices. These could be named 'knowledge points', where knowledge passes through as knowledge flow when transmitted to the outside, e.g., private firms or public institutions; as seen in Figure 3-6.

Figure 3-6: The Danish public research sector and its knowledge flow and knowledge exchange points



In the discussion among researchers about collaboration between industry/society and research units some have argued that more emphasis on research collaboration with the outside world would reduce other forms of research, especially basic research, because of limits of time. But based on Norwegian figures it was found that researchers with funding from industry publish more often in journals, books as well as in reports than others (Guldbrandsen and Smeby, 2002). This may also be the case in Denmark.

3.1.2 Researchers Attitudes and Actual Collaboration in a Knowledge Exchange Perspective

Collaboration between researchers can be described as a continuous range from feedback from one colleague to another at a department, to co-operation agreements between organisations; where agreements can be a step to a fusion between organisations, feedback between individual researchers can be regarded as the minimum collaboration that one could obtain at a research institution.

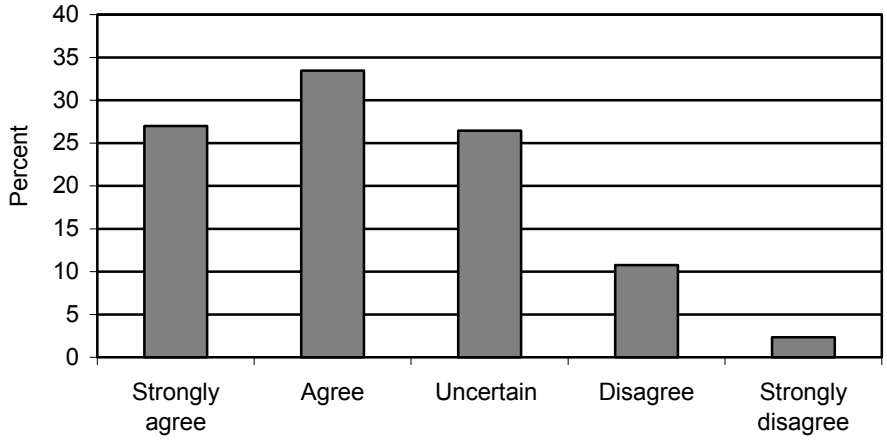
In some situations a *critical mass* of researchers at a department or institutions has been mentioned. The rationality of this *critical mass* argument is the recognition of the importance of immediate response and feedback from colleagues within an organisation to the research results. This ongoing feedback or response system has traditionally been integrated in the academic research world, and it can be argued that this is the first level of 'peer review' of results and projects. The rationality is connected with the actual amount and quality of the collaboration, an amount and quality that might be accessible from researchers in other organisations.

Beside the collaboration within the department/organisation most researchers collaborate with researchers at other departments and centres. This collaboration might take form as a formal or informal network, collaboration in research projects, and co-operation between organisations including exchange (mobility) of researchers in shorter periods. The sort and the degree of the collaboration is dependent on the main subject areas (natural science, technical science, medical science, etc.) as well as the sort of organisation.

The department is the most important place for feedback and collaboration for most scientists. The study of *Dynamic and innovative research environments* (Graversen et al. 2002) showed that the managers at these environments place a lot of effort in this internal collaboration. The managers supported informal as well as formal collaboration, e.g., café areas, internal workshops, and it was found that the researchers at those environments often worked in teams. Another Danish study supports this finding (Jacobsen et al., 2001).

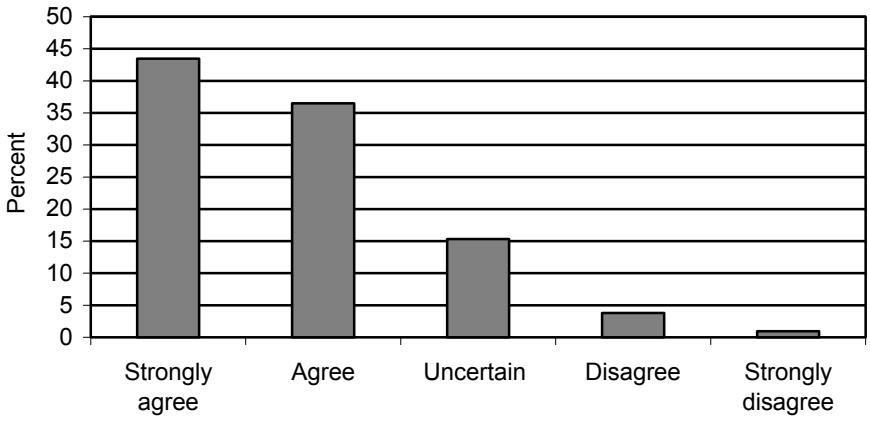
But as seen in Figure 3-7, the majority of Danish university researchers found that they needed more internal collaboration, i.e., there is a lack of internal collaboration at a number of Danish university departments, obviously not because the researchers don't want to collaborate but because the research environment has not developed proper ways to do so. The study of Jacobsen et al. (2001) describes examples of such environments.

Figure 3-7: Answers to: *There is a need for further internal collaboration at the department* from researchers at Danish universities in 2000/2001. Percent



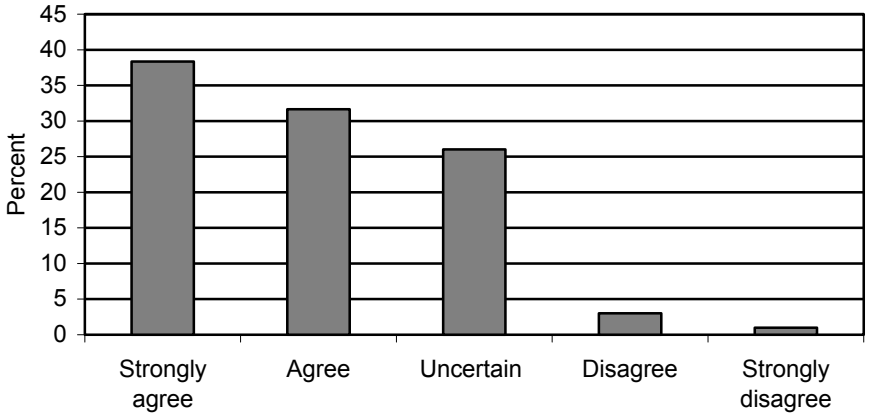
The amount of collaboration per researcher to researchers outside the department may be dependent on the size of the department: at a minor department it is more often necessary for researchers to achieve feedback externally, because (s)he might not be able to find a colleague within the institute who has the proper knowledge, and consequently the researchers more often develop close relations to researchers from other organisations. On the other hand the number of collaborations per department might depend on the number of researchers: a larger number of researchers will create a larger total number of collaborations with the outside. Because of the large differences in size of departments at the universities as well as at the GRIs, the amount of collaboration out of the department differs in number as well as in form. At a number of minor university departments the collaboration with the outside research world depends on the individual researcher and his/her personal network. At larger departments and departments where teamwork is dominating, the collaboration is more often collaboration between networks as well as individual networks. As seen in Figure 3-8 there is a clear support to collaboration out of the department and universities.

Figure 3-8: Answers to: *All researchers ought to collaborate with researchers from other scientific areas/other institutes in projects at least sometimes* from researchers at Danish universities in 2000/2001. Percent



Several reasons for the positive views on collaboration with others sectors could be noticed, among these that it is *inspiring* to work together with researchers in other organisational set ups, as seen in Figure 3-9, this is the case.

Figure 3-9: Answers to: *It is scientific inspiring to collaborate with researchers from outside the universities e.g. researchers from governmental research institutes or the private sector* from researchers at Danish universities in 2000/2001. Percent



Collaborations can also take place *between public organisations*. In 1999 a study was made on co-operative agreements between the Government Research Institutes (GRI) and the universities. All GRIs received a questionnaire about their agreements with universities and they were asked to mail the text of actual agreements.

The agreements were different in many ways: some were precise and specific, e.g., sharing time in and costs of laboratories, others were general and in some cases more a signal, intentionally, than a binding agreement. One GRI[1] had 34 formal co-operation agreements, 23 informal agreements, and 10 agreements where the degree of formality was unclear. The agreements were with universities and university departments in Denmark as well as a number of other countries. This amount of agreements reflected that the research at the institute can be characterised by a high degree of interdisciplinary.

Most GRIs had a more moderate number of agreements covering a number of issues. 28 of the agreements were closely text-analysed and then grouped as seen in Table 3-1.

Table 3-1: Co-operation agreements between Government Research Institutes and Universities in 1999 by the degree of binding-ness and specification

	Very specific	Specific	General
Very binding agreement	15		2
Binding agreement		5	4
Intentionally, agreement with a symbolic value			2

Source: Langberg and Sørensen, 2000.

In some cases intentionally agreement have developed into a tradition of the planning of conferences, joint participation in international projects etc. In other cases, informal traditions resulted in joint projects of different kinds. The different areas of co-operation are seen in Table 3-2.

[1] The former Department of Toxicology, at the Danish Veterinary and Food Administration (FDIR), FDIR has reconstructed the organisation since 1999.

Table 3-2: Number of Government Research Institutes collaborating with universities and university departments, by issue and kind of agreement

Collaboration on	Number of GRIs with formal agreements on the issue	Number of GRIs with other forms of agreements
Planning of conferences	6	3
Joint participation in international projects	6	1
Research equipment	12	0
Material, data	12	2
Laboratories, auditoriums, etc.	13	1
Exchange of researchers (temporary mobility)	7	1
Consultant work	5	0
Joint research projects	14	3
Publications (including Working paper series)	11	2
Libraries	3	0
Seminars	7	2
Teaching in general	9	0
Teaching at PhD level	16	4
Teaching at graduate level	11	3
Joint professorship	7	2

Source: Langberg and Sørensen, 2000.

While researchers at the GRIs in general need to inform their department manager or director when they enter a collaboration project and traditionally have done so, this has not been the tradition at the Danish universities; though this has been changed within the last few years: if the collaboration is formal in any way, agreements between university researchers and researchers from other institutions or private firms have to be signed formally at the department level or higher levels at most universities.

Research conferences offer the opportunities of feedback on research projects when a paper is presented, information on new results from other research

institutions, and an important means to find collaboration-partners. Research conferences are time consuming and some researchers find that they travel too much. But as seen in Figure 3-10 and 3-11 the researchers in general find conferences inspiring and necessary.

Figure 3-10: Answers to: *Participation in scientific conferences and congresses is necessary for the inspiration of the (future) research* from researchers at GRIs in 1998. Percent

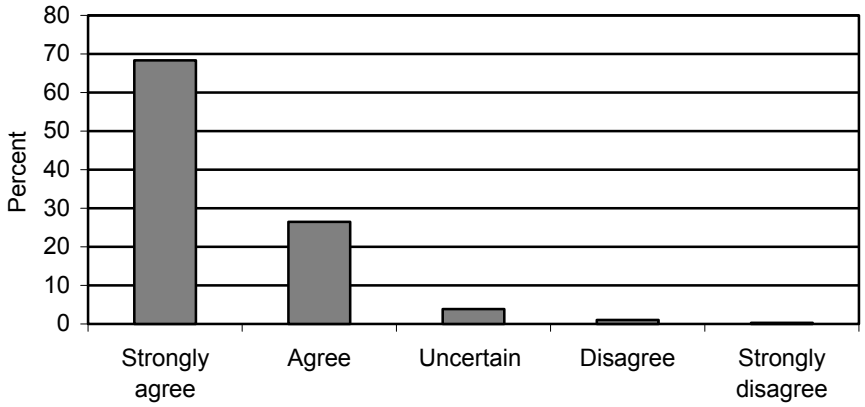
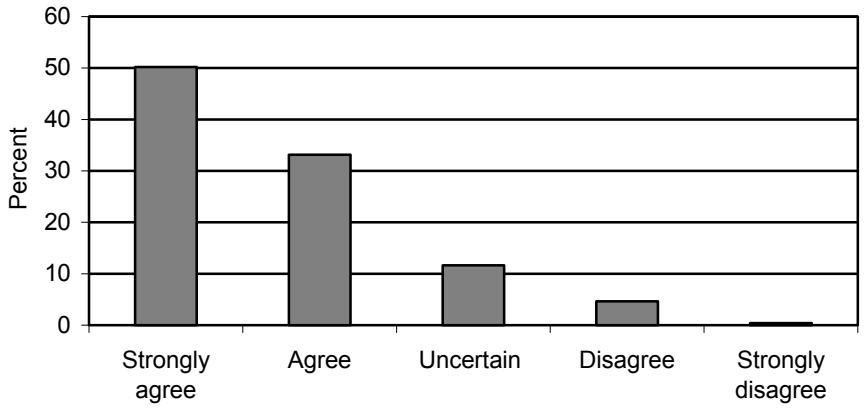


Figure 3-11: Answers to *Participation in scientific conferences and congresses is necessary to check the quality of the research* from researchers at GRIs in 1998. Percent



Collaboration between *public and private organisations* can be informal as well as formal. Formal co-operative projects will normally be known at the administrative level, but the number of researchers involved, the impact of the collaboration on productivity, etc. will seldom be accessible. It is therefore difficult to count the collaboration or measure the impact. Hence, indicators of the collaboration could be the number of R&D projects financed by the private sector, and this can be found in the R&D statistics.

Table 3-3: Research and development financed by private firms at Danish public research institutions 2000. Percentage based on number of departments/institutions

	Danish firms	Foreign firms	Danish and Foreign (Mix)	Total
Universities	41 %	2 %	6 %	50 %
Government Research Institutes	21 %	2 %	37 %	60 %
Total Public sector	31 %	3 %	10 %	44 %

Note: The unit in the Danish R&D statistics is department on large institutions as universities, and the whole organisation at the minor.
Source: Graversen, 2002.

As seen Table 3-3 the GRIs are more likely to have R&D projects financed by private firms than university departments. It is also seen that a large percentage of the R&D projects at the GRIs are financed by Danish as well as foreign firms, where the university departments have a larger percentage financed by Danish firms alone.

International co-operation and collaboration have a large variety of forms. It can be seen from the individual perspective as seen in Table 3-4 or it can be seen from the national level as done in the study by Graversen and Siune (2000), where the focus was on participation in the 4th EU Framework Programme.

Table 3-4: University researchers that work or had joined international collaboration beside their ordinary work in 2000/2001, by type of collaboration

Type of international collaboration	Percentage that have joined
Study-period abroad (after graduation/MA-degree)	21 %
Part of an exchange program	10 %
Part of international project	42 %
Other types	7 %

3.1.3 Researchers' Attitudes and Actual Mobility in a Knowledge Exchange Perspective

Mobility can be seen as a possible way to access new knowledge for individuals as well as for organisations, and mobility can be viewed as a key issue in the knowledge distributions within the research sector as well as in other sectors.

Mobility among individual researchers can be caused by individuals desire to change job position, e.g., from associate professor to full professor; for change of scientific area, or for other reasons as seen below.

> *When I was at the GRI - well I had to have support from my research director and the director if I wanted to work on a special issue or project - then, when it was supported, it was no longer my project, it was the project of the institute, so I was given a lot of support: secretaries wrote my application and took a number of copies etc., colleagues read it and gave me advice, I could focus on the application and did not need to bother with other projects, and so on. Here at the university it is my project, I have to do all the paper work, copy everything myself, but it is my decision to work on the project, it is not a decision taken by the director.....and I still have to teach..... I prefer to be here...*
>
> Researcher at a university 2000

But mobility can also be *forced* as a consequence of lack of job, which forces the researchers to change workplace, sector, or even scientific area because this is the only way to stay in the labour market.

In this section focus is on the mobility of individual researchers at universities and governmental institutions. The information used is information on their former

workplaces. Mobility can be defined in different ways. In this report the following definition will be used due to the kind of information available:

- **Mobility between work places** is defined as at least 1 year of employment at another place than the university/GRI, where the researcher is presently employed, the mobility between work places is counted during the entire career.
- **Mobility between education places** is defined as a shift between the university where the researcher graduated (MA, MSc. etc.) and the university where the researcher received the PhD-degree /doctoral degree.
- **Mobility between scientific fields** during the education is defined as a shift between the six main scientific fields from the graduate education to the PhD-degree.

Other ways of describing the mobility in a Danish context can be found in Graversen (2001).

Younger researchers, e.g., research assistants, PhD-students, Post Docs, researchers, or assistant professors will normally have contracts limited to a 2- or 3-year period (see section 2.4.1). This can result in forced job mobility from one research institution to another, depending on the actual situation on the labour market and the possibility for funding of research projects. Most Danish researchers are therefore likely to have been employed at different institutions during their career, a mobility that is not necessarily the result of free choice.

For some of the researchers, a movement from one geographical area to another will create conflicts with their family life, because the researcher's spouse needs a new (attractive) job and the children have to change schools. This, combined with large fixed costs of moving, reduces the job mobility rates among established (older) researchers, because the wage differentials in the publicly financed research institutes in Denmark are so low that the changes in wage due to job shifts seldom covers the costs. A professor mentioned this point during an interview: he would have liked to change position but the economic as well as social costs of changing positions had restricted him.

Table 3-5: Work place mobility. Percent

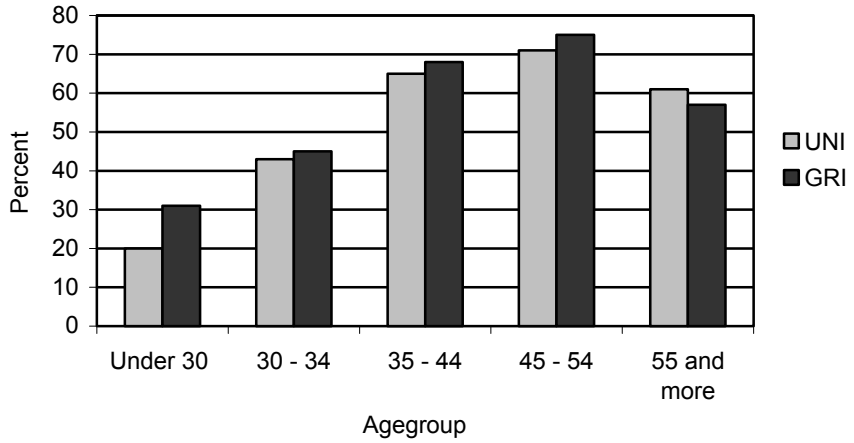
Employment at another work place than the present (at least one year)	University researcher (2000)	Researcher at GRIs (1998)
University in Denmark	19*	33
Governmental Research Institute in Denmark	6	10*
University outside Denmark	1	1
Research Institute outside Denmark	16	8
Ministry in Denmark***	8	6*
EU-institution	4	3
Private company/organisation	13	7**
Other	13	25
Work experience from other work place than the present. Work place mobility rate	54	61

* Other university/GRI than the actual workplace.
** Private company/organisation within the same area as the GRI.
*** The ministry that the GRIs mainly is connected to (see Table 2-3).

The job situation in the Danish academic labour market has changed during the last two decades. In the beginning of the 1980s there was high unemployment and very few jobs available at the universities, a situation that was also found during the 90s within some area. In the same period a number of the GRI were restructured. This, combined with that a PhD-degree or equivalent (see section 2.4.1), became a requested qualification for the acquirement of a job as assistant professor or researcher made it more difficult for new researchers to enter the research institutions.

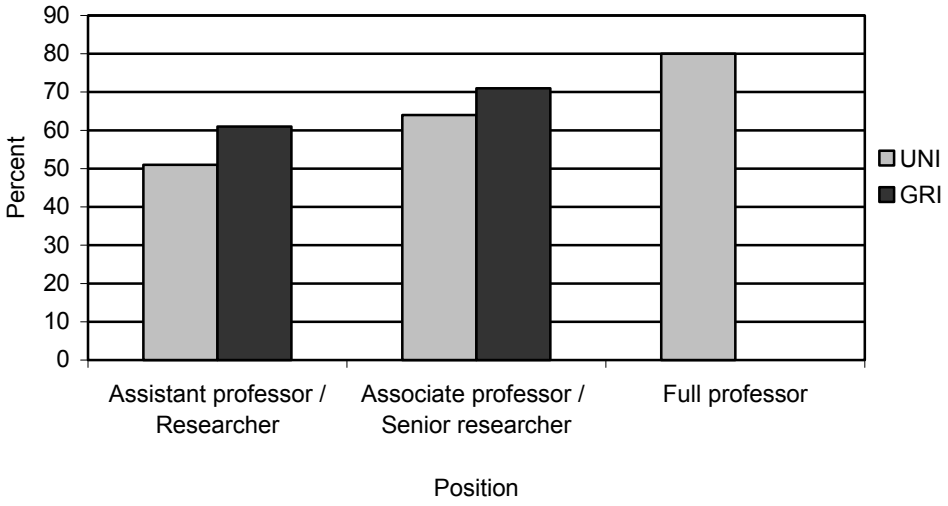
As Figure 3-12 shows, the workplace mobility is increasing by age although the 'oldest' are less mobile than the 'next oldest'. This can partly be explained by the fact that the 'next oldest' were the ones experiencing a difficult labour market situation in the early 1980s.

Figure 3-12: Work place mobility rate by age group. Researchers at universities and government research institutes. Percent



Professors as well as associate professors and senior researchers are generally older than other researchers and they are therefore more likely to have been work place mobile since a longer career provides more time for job shifts between work places. Normally it last at least 6 years to reach the position of associate professor and longer to reach the level of full professor, that often will include a change of institution. As Figure 3-13 shows the work place mobility is correlated with the job position as expected.

Figure 3-13: Work place mobility rate by position. Researchers at universities and government research institutes. Percent



Although there was no tradition at Danish research institutions for researchers to have a PhD-degree before 1985, approximately 63 percent of the researchers employed at the universities in 2000, and 46 percent of the researchers employed at a GRI in 1998 had a PhD- or doctor degree.

The probability of having a degree is dependent on age: the share of researchers with a PhD increases at first and then decreases with age. Out of the university researchers who have a PhD- or doctor degree only 26 percent took the PhD at another university than the one where they graduated.

Individuals without a PhD- or doctor degree are less work place mobile that others, and the individuals having a PhD- or doctor degree from another university than the one they graduated from tend to be more work place mobile than others, e.g. the workplace mobility is correlated with the mobility between education places. The difference in work place mobility rates is almost the same between the age groups regardless of the presence of a PhD degree (no interaction effects are found).

The scientific fields mobility is measured by a shift in scientific fields between the graduate education and the PhD-study or doctor degree. Among the researchers with a PhD, 21 percent have changed major scientific fields. Table 3-6 shows the

mobility rates for the six main scientific fields. The agricultural and veterinary science fields have the largest scientific fields mobility, compared with the graduate education field.

Table 3-6: Scientific fields mobility, by primary scientific area. University researchers. Percent

Scientific area, primary education (MA, MSc etc.)	No PhD- or Doctor degree	Same scientific area	Different scientific area
Natural science	42 %	50 %	8 %
Technical science	45 %	46 %	9 %
Medical science	47 %	49 %	4 %
Agricultural and vet. science	41 %	43 %	16 %
Social science	56 %	43 %	1 %
Humanities	50 %	46 %	4 %

There is no simple correlation between the work place mobility and the scientific fields mobility. However, there is a connection between education place mobility and scientific fields mobility. Of the PhDs who had changed education place, 49 percent had also changed scientific field. The explanation could be that a few of the Danish universities are specialised, e.g., when a PhD students change to one of these universities (s)he will change scientific area.

It is often assumed that men and women have different mobility rates but this is not the case in Denmark: in a model involving difference in age as well as employment category, such gender-differences were not found.

From a knowledge management approach it should be expected that the mobility of the researcher has an impact on attitudes toward collaboration and research management. As Table 3-7 shows this is in fact the case. The *work place mobile researchers* seem to be more collaborative on all levels. They also find it natural to diffuse knowledge by teaching students and they find a need for a stronger visible research management at the Danish universities. The work place mobile researchers deviate significantly in attitudes compared with the less work place mobile researchers.

Table 3-7: 'Work place mobile' university researchers' attitude towards job related statements

Statement with a five points Likert response scale (From fully agree to fully disagree)	Work place mobile researchers *
There is a need for further internal collaboration at the institute	Agree more often
I have to spend too much time on teaching	Disagree more often
It is scientific inspiring to collaborate with researchers from outside the university sector e.g. researchers from governmental research institutes or the private sector	Agree more often
There is a need for initiatives within research policy on corporation between the university and the private sector	Agree more often
There is a need for more research management at the universities	Agree more often

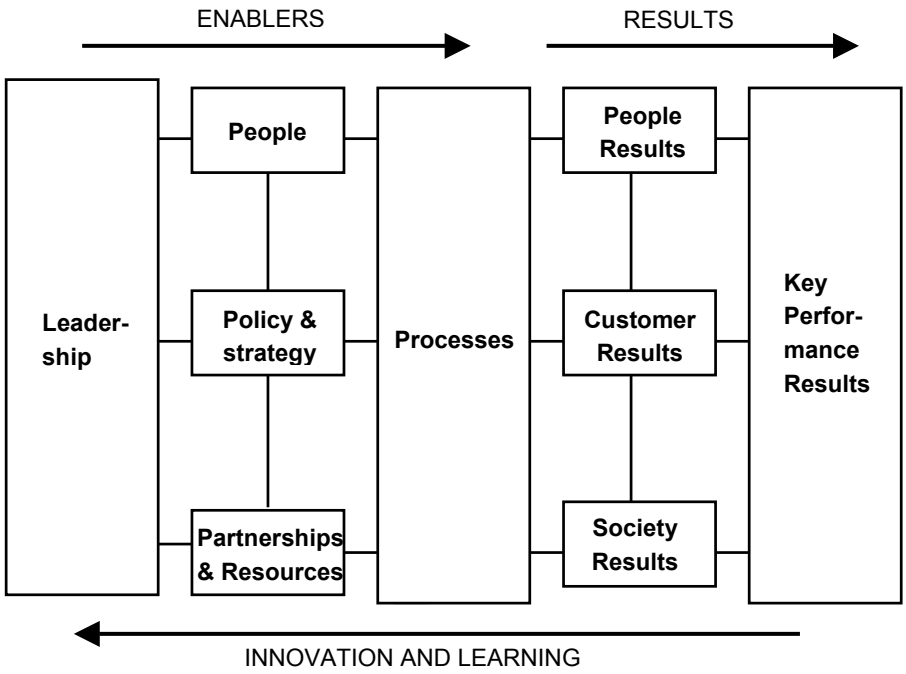
* Tested in log-linear models using 5-percent significant levels

3.2 Total Quality Management, The Excellence Model

The concept *Quality Management* was introduced in Europe in the late 1980s as a management concept in the private sector. The concept was inspired and built on ideas from quality control of products, including statistical control of a production process as well as external controlling. The central idea can still be described as *controlling processes* by statistical means but it has now emerged from the simple product control to control of the total chain of processes within the firm. The model was named *Total Quality Management* (TQM) from the 80s to the mid 90s, where the model changed *brand* from TQM to *The Business Excellence Model* and later again to *The Excellence Model*, as it is called today. A central part of the model is (still) the element of external control: external controllers inspect the companies.

The first version of TQM focussed on product, customers and employees and the interaction between these items. The model was from the start built partly on experience from the companies using the concept. When the system was introduced in the public sector, *customers* were often changed to *users*. In 1996, the model changed radically and has since then taken on the structure seen in Figure 3-14.

Figure 3-14: Structure of the Excellence Model



All parts in the model are made measurable by a number of measure-points, e.g., the employee's satisfaction is measured by a (standard) survey, the quality of the product is measured by number of errors, etc. When measuring all and the same parts of the model several times, it is possible to compare the management from one period to the next as well as it is possible to compare organisations. This possible comparison between organisations was supported by the introduction of a number of prizes: local prizes like the Danish Quality Prize, in two versions: a private and a public (SCKK, 2000), and overall European Prizes.

As seen in Figure 3-14 the political context of a public (governmental) organisation is missing - unless the *customers* could be identified as the politicians; but the politicians are more likely to be identified as owner or stakeholders. However, they are not stakeholders like stakeholders in a private company: they are not interested in the profits of the organisation.

In Denmark some research institutions have used the Excellence approach; as seen below Risø used a revised version, while Danish Forest and Landscape institute only was inspired by it.

Within the last decade the directors at Risø have focussed more on strategic development and management than earlier and in a Danish perspective developed a unique awareness of management of research. This awareness has resulted in a number of initiatives, such as management courses for senior researchers as well as for Ph.D. students. It became an issue to make the management effort coherent at all levels, e.g., from the research project-level to the overall directors. As seen below the TQM- or Excellence model were regarded as a model that could be used:

> *"When I have talked with research managers at Risø, they have had many interpretations of the meaning of research management - very often they refer to a very limited version of management: management of their own research - it is important to most of them that they themselves are active researchers - and they have focussed at the scientific development as such. To me research management is broader: you have to realize that at a modern research institution it is not enough to produce articles in highly rated journals and to be among the best when it comes to citations - this is important, otherwise it is a disaster - but you have to have a policy at other levels: you have to have a close relationship with the industry, with the public, etc. ....When you start to discuss research management in this broader version with highly educated researchers that have a long record of managing research projects, it is important to have a tool, a kind of check-list, a model that everyone can relate to - the Business Excellence model is a perfect tool to use in this case, it is a holistic model, not a model that focuses on a limited area".*
>
> Vice-director at Risø, 2000

Beside the model's capability to capture management at a number of different levels, the vice-director mentioned that the model made the communication between board members from the private sector and the management at Risø easier, and that the model seen from the perspective of a private manager could be used as PR toward the private sector:

> *"We have industrial managers in our board - one of them mentioned that it should be noted, when we are in contact with industrial managers, that we use a management model like the Business Excellence model - it is known to them - in order to communicate to them that we can manage".*
>
> Vice-director at Risø, 2000

When the model is used in industry it can be integrated with systems of certification, i.e., quality checks of the production and the laboratories in order the

label the product with '*ISOXXXX-certified*'. This is a rather expensive procedure partly because it has to be conducted by external controllers. Such a certification has been discussed at a number of GRIs, but as at Risø the strategy has not been focussed at this:

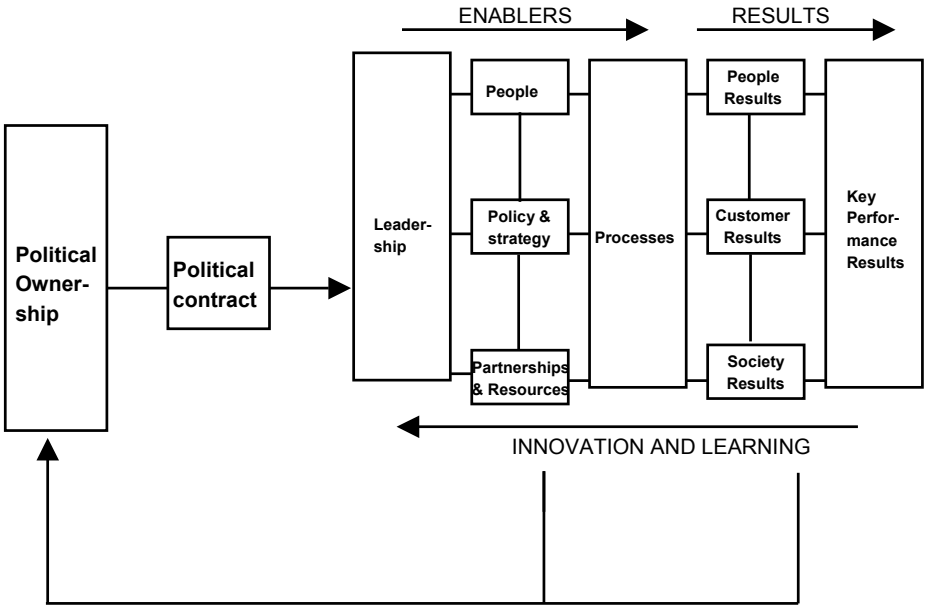
> *"We don't use the part of the model that can be focussed on certification, it is not a part of the strategy at Risø, that the labs should be certified - unless of course it is necessary in order to get the order in the first place - we do conduct a number of analyses that others pay for - but as a strategy - no - some of our labs are checked in other ways, i.e., the labs used for biotech".*
>
> Vice-director at Risø, 2000

As mentioned above, it could be a problem for public institutions that the model mostly is based on management experience from the private sector. This problem has been solved by adding an element to the model:

> *"At a public research institution as ours it is important to have a focus on the 'Political ownership' - it is important to realize that even if you have a four year contract as we have - the politicians are active - you cannot expect to have 'peace' in a four year period, you have to deal with it all the time - it is not at part of the standard model, but it can be added to it".*
>
> Vice-director at Risø, 2000

This addition to the standard model is seen below in Figure 3-15; the extended excellence model was based on case studies in the public sector (Schou et al. 1998). It is this revised model, and not the standard model, that was used at Risø.

Figure 3-15: The Extended Excellence Model



The Danish Forest and Landscape institute (FSL) is another of the GRIs that has focussed on Quality Management. FSL was based on a number of fusions from 1991 and the next couple of years between different institutions with different traditions according to financing, research and work in general. After the fusion, FSL has grown with respect to number of publications, number of researchers, etc., and a number of new employees entered the organisation. In the mid 90s it became clear that the organisation needed a common management culture and the director took a number of initiatives in order to establish one. The administrative managers, the research managers of which some had just been appointed, as well as the director entered into a management process in some cases supported by external consultants. The director described this process in an understated statement: "*we were fumbling around*".

The newly appointed managers at department level were recruited from positions as senior researchers, e.g., they did not have any formal managerial training beside their academic research background. The managerial training process was focussed on workshops and seminars where the management group could consult each other as well as invited external consultants. Among the invited consultants was a firm specialising in Total Quality Management, and the management of FSL

focussed on this in a period, but they did not implemet the system because of its costs relative to the gain that the institution would have if the system was introduced.

The costs of implementation of TQM at FSL were at two levels: direct expenses to the external consultancy firm when the system was to be implemented as well as to the external controllers, and indirect costs like time used by the employees. A rise in prices could not cover the costs of certification of the laboratories, because a rise in prices was not an option, nor could a rise in demand be expected.

The management of FSL was aware of the Public Quality Prize, but this was not the reason for the interest in the model, "*the models attractiveness was it capability to function as a checklist".*

Consequently the awareness of the TQM model supported the awareness at all level of management from inputs, e.g., employees, to results: costumer- or user-satisfaction and quality of publications.

As other GRIs FSL produced a large amount of newsletters as well as reports, publications that not necessarily have gone though the 'quality check' such as a referee-procedure. Like other GRIs the institution often passed publications to external reviewers, and they had had an internal feedback from department managers and the director, but now the institutions introduced a '*total quality-check-system*' of all publications, a quality check involving external researchers as well as lay-out-specialists etc.

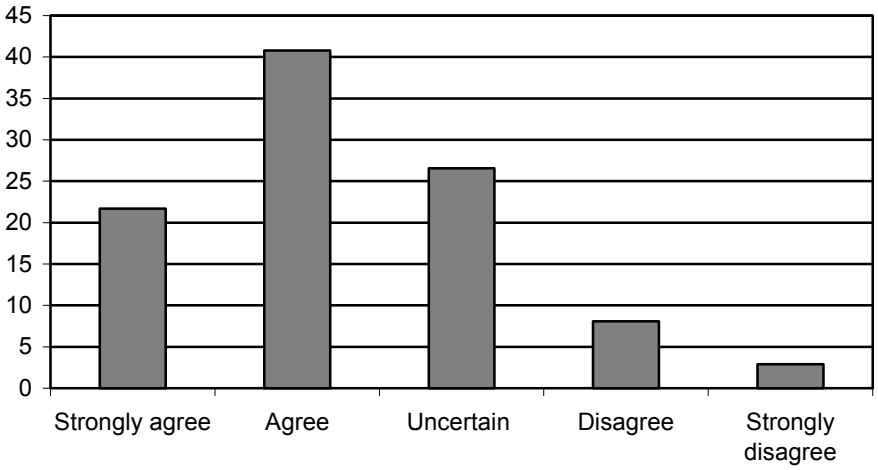
The work on internal managerial issues at FSL changed focus when the institution entered into the close strategic relation with a university department in 1998.

3.3 Contracts, Milestone systems and Benchmarking at the Universities and Government Research Institutes

Contracts between public institutions and their ministries have together with *milestones and benchmarking* been introduced in the public sector as management tools in the last decade. The contracts are sometimes labelled *performance contracts* or *contracts of results.* At some GRIs, contracts between the institution and the ministry have been in use for several periods, e.g., since 1993 at *Risø* and since 1996 at *Danish Forrest and Landscape Research Institute (FSL).* Parallel to this, a number of GRIs have introduced milestones at the department-level without a formal contract at the top level of the institution. In 1998 contacts and milestones were to be found or introduced at almost all levels at the GRIs and had been widely

discussed among the researchers. As seen in Figure 3-16 more than 60 percent of the researchers at GRIs agreed that the introduction of milestones at the department level would improve the quality of the research in the long run.

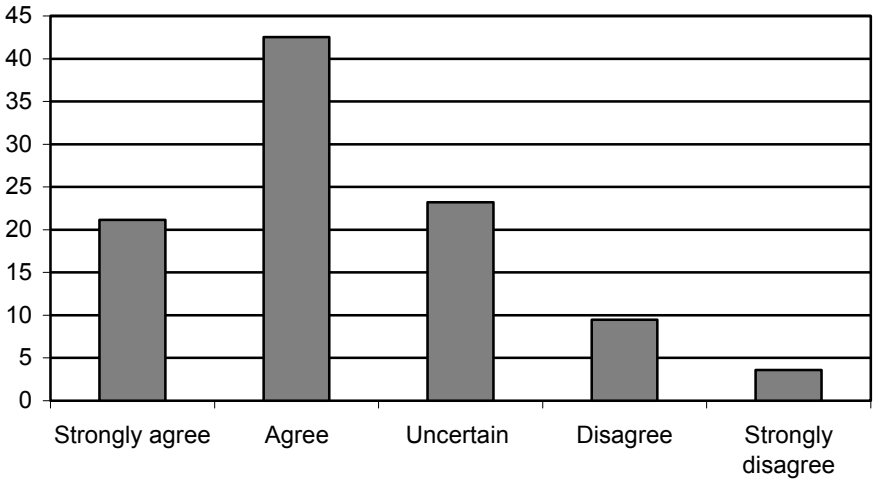
Figure 3-16: Answers to: *Introduction of milestones at the department level would improve the quality of research in the long run* from researchers at Danish GRIs in 1998. Percent



An analysis of the answers showed that the attitudes were connected to experience on milestones, e.g., that researchers on institutions with experience on contracts and/or milestones did agree more often than others.

The attitude to milestones at the department level was closely correlated to the attitudes to milestones on the individual level. The answers on this attitude-question are shown in Figure 3-17.

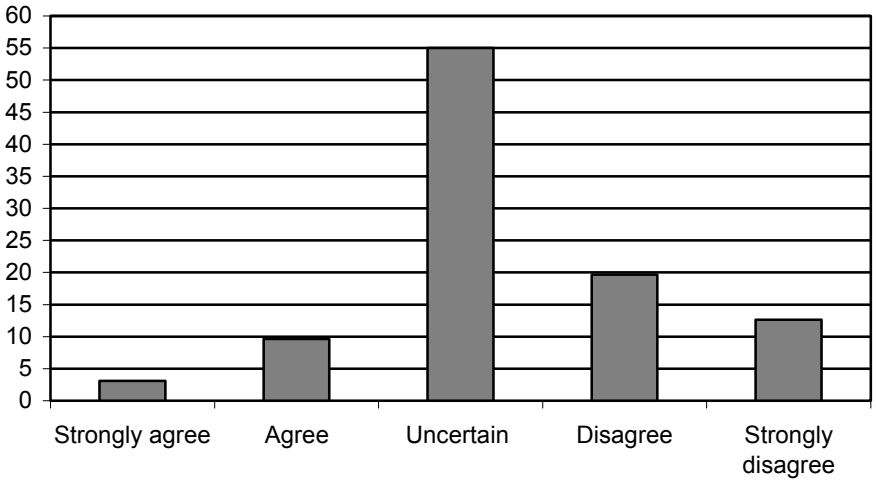
Figure 3-17: Answers to: *Introduction of milestones at the individual level would improve the quality of research in the long run* from researchers at Danish GRIs in 1998. Percent.



Contracts between the universities and the ministries were introduced in 2000. The ideal contracts were presented as results of a top-down process combined with a later bottom-up process. These processes should be based on strategies for the future development and the expected results on department level, on section level, and on the university level. With a decentralised management structure it was expected among the heads of the universities as well as among others that a large number of the researchers had been involved in the discussions of the contracts, but rumours said that this was not the case.

As seen in Figure 3-18 most of the university researchers were uncertain on whether there had been an intense debate or not.

Figure 3-18: Answers to: *There was an intense debate prior to the signing of the contract between the university and the Ministry of Research* from researchers at Danish universities in 2000/2001. Percent



This result indicates that the top-down and bottom-up had not taken place in the way that many including the managers had believed; two other questions in the same survey as well as qualitative interviews from the same period pointed in the same direction.

> *"I don't know what is written in the university contract - I have never seen it. Nobody ever bothered to give me a copy, and I have not searched for it. I do know there was a process around it ..... of course the head of department was involved .... if you were to stop an associate professor at the gallery outside and ask about what was in the contract, I don't think anyone could tell you. So you could say, it does not matter."*
>
> *University researcher 2000/2001*

It might be assumed that after a period with contracts and milestones at the universities, these contracts might be as integrated in the university systems as at the GRIs, and that the university researchers might change their attitudes, and not only be more positive but also regard contracts as important for the quality of the research.

While the contracts have been introduced to all public research institutions, benchmarking is not (yet) a managerial tool all over.

The concept *benchmarking* was first introduced in the private sector in Denmark, and possibly because of the rather simple approach, it was quickly introduced in the public sector as one of the managerial tools that were connected to the Danish version of *New Public Management.* Benchmarking has also been mentioned as a possibility by the Ministry of Research in connection with the university contracts.

Benchmarking is often connected with milestones because both tools often count results: a milestone could be a specific number of articles written within a period but it can also be that a solution of a specific problem is found. The number of articles can also be used in a benchmarking project, but in this case the information is used by the organisations in order to perform better in the future and not as an achieved goal.

The fundamental idea behind a benchmarking process is that one or more organisations among the group of organisations in the benchmarking project are identified as *best practice* in a specific area, and that all the organisations enter into a *leaning process*, where the *best practice* is the optimal representation of the target in the first round. Later the targets can be discussed in a dynamic, strategic set up that gives all organisations including the *best practices* a possible new look at their strategies. Differences between the *best practice* organisation and the others are used as information nodes.

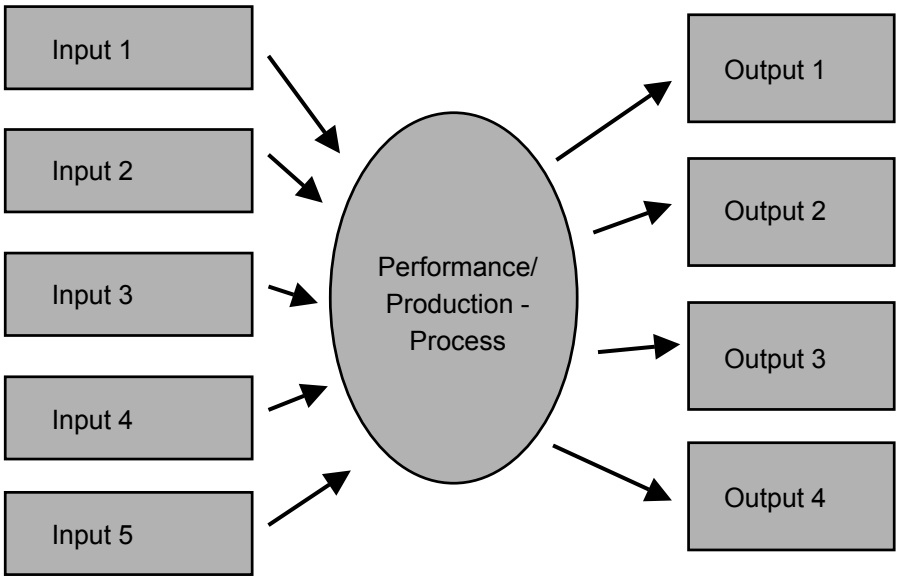
Benchmarking can be carried out by two or three benchmarking partners that enter into a co-project, or by a number of organisations or firms that form a benchmarking group. The organisational form is dependent on the goal of the project. In some cases an organisation may use benchmarking made by other organisations, in this case reports from similar organisations can be used as a starting point.

Behind the idea of a benchmarking process lies the picture of a performance- or production- function as shown in Figure 3-19. As seen, the performance/production function (p/p-function) is the generator of the outputs based on the inputs. Universities and other public research institutions are in a number of ways similar to other knowledge organisations, and the p/p-function can be described as a production function as well as a knowledge generative and transformation process.

In Denmark there is (in contrast to other countries such as Norway and Germany) little information on research output beside yearbooks. In some scientific areas like natural and medical science, where almost all research publications are written in English and published in international journals that are ranked by different criteria, the departments/institutions are aware of their actual rank, their citation index, etc. However, in areas as humanities and parts of the social science this is not the

case. Analyses based on publications can be found within a number of scientific areas (Economics in Europe: Kalaitzidakis et al., 1999; all areas in Germany : Berghoff et all, 2002).

Figure 3-19: The production/performance function and its inputs and outputs.



An attempt to make a quantitative benchmarking within the social sciences in Denmark, based on information from yearbooks with the use of DEA (Damm, 2001), was criticised from a number of heads of departments. Some argued that the departments should have been anonymous, others that a benchmarking that included different areas such as sociology, law, and economics should not be performed at all. Later some departments within economics have started a benchmarking project (Langberg, 2002c).

3.4 Conclusive Remarks on Actual Research Management within the public sector

In the beginning of the 1990s there was very little focus on managing human resources within the public research sector, and management was often regarded as a purely administrative task dealing with the implementation of new rules and

financial problems. Attempts to plan strategically were made at some governmental research institutes, but this was seldom the case at universities, where the decentralised management structure remained. Still at a number of research environments at GRIs and university departments directors, head of departments, and local research managers managed to develop dynamic research units with a growing knowledge base.

The knowledge spiral, mentioned in section 3.1, focuses on the transformation and exchange of knowledge from one individual to another, from tacit knowledge to explicit knowledge and the other way round in the context of one organisation. This transformation of knowledge can be seen as one possible way to explain the growth of human capital of single individuals and within organisations. The idea of a knowledge spiral can give insight to managers who want to support knowledge exchange and growth within the organisation. The model is appropriate for a decentralised structure that depends on the single individuals collaboration such as collaboration based on researchers *research interest* as it is found at universities and GRIs.

Most of the public research organisations join collaborate projects with other institutions, public as well as private. Some of the managers are aware of the possibilities of knowledge exchange within the Triple Helix, i.e., collaboration between the government, the private (production) sector and the research sector, and they manage in networks built by agreements and trust rather than control. This kind of knowledge exchange might be more extensive in the future.

Management models like the TQM- or Excellence- models integrate the research interests from the research society with the legitimate control of stakeholders, e.g. the state (taxpayers) at public research institutions but they are costly to introduce, it is therefore more likely that the research managers will use these kinds of models as inspiration for changes in the managerial systems instead of introducing a total implementation of it at the research institutions.

The ideas of contracts, milestones, and benchmarking are new to a number of public researchers, but they will probably be introduced widely in the Danish public research sector in the future, and it may be expected that it will be more accepted by the researchers when they have had more experience with it.

Generally speaking the lack of management so far at a number of levels gives a possibility for a better research performance in the Danish public research sector in the future. Taking the experience from the ‘dynamic research units’ into account, and given that the management is capable of managing the human resources that the researchers posses, and the research management achieve legitimacy among

the researchers; then this can be expected because a large numbers of Danish researchers do support changes. On the other hand it might be expected that a number of growing research environments will suffer in the short run and some of them might even disappear because of lack of economic resources during the reform period; as well as it might be expected that managers that are not regarded at legitimate by the researchers will face large problems.

In general it is to be expected that in the future successful research managers in Denmark will need to have two forms of qualifications: scientific qualifications as well as managerial.

4. A model for the Performance Function of Research Management

The concept *Research management* is used in different meanings and at different levels as seen in the former sections. Research management is addressed to the transformation process that is found between the inputs to the research organisation and its output, where the core issue for a manager is to secure that the inputs are used in such a way that important new knowledge is developed effectively, that resources are not wasted, that the research conducted is useful at least to someone, and that the results are presented in such a way that the results are available to others. In short it can be said that:

The aim of research management is improvement of the performance function that transforms the constant flow of different inputs to research performance process into new important knowledge.

In this section the main issue is the development of a model for research performance function that can be used to assess managerial problems in research management and can be used analytically. In subsection 4.1 the model is presented in a simple static version. A dynamic version is described in subsection 4.2. The section ends with some comments on the function connected to economic growth in subsection 4.3

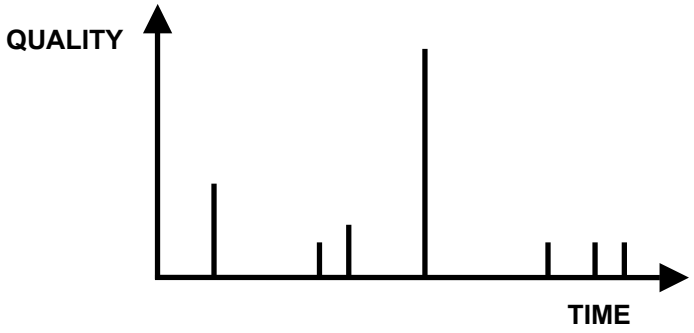
4.1 The Static Research Performance Function

The research performance function describes the process where research ideas are transformed to new important knowledge that can be used in society. Ideas and other resources are inputs to the performance function, articles, books, presentations, etc., can be regarded as output. A central part of the performance function is the decisions that have to be taken at different stages based on different kind of information and by different managers – and by the researchers themselves. The outcome of the performance function is dependent on the probability of taken the right decisions at each stage. In dynamic research environments a number of projects at different stages are to be taken into account, some are nearly finished, other hardly discussed and the scientific as well as the societal context is changing all along. Consequently the research performance function is dynamic, the presentation in this section of a static function is to be regarded as a step on the way to develop a dynamic model.

The primary input to the research performance process are ideas, themes and questions combined with resources as hours of work, technical equipment such as

laboratories, etc. The production of research ideas is in the core form creative work, i.e., there is no simple function that can describe the way initial ideas are made. But it can be assumed that the amount as well as the later observed quality of the initial ideas are a function of the researchers amount of knowledge in different forms as well as the researchers' *research interests*. The initial ideas might be in tacit form, i.e., not possible to pass on to others. It is also assumed in the model that the ideas occurs randomly i.e., the idea can be regarded as a random variable. The occurrence and the embedded quality of the ideas could be exemplified as seen in Figure 4-1.

Figure 4-1: The occurrence and embedded quality of primary research ideas, themes and questions



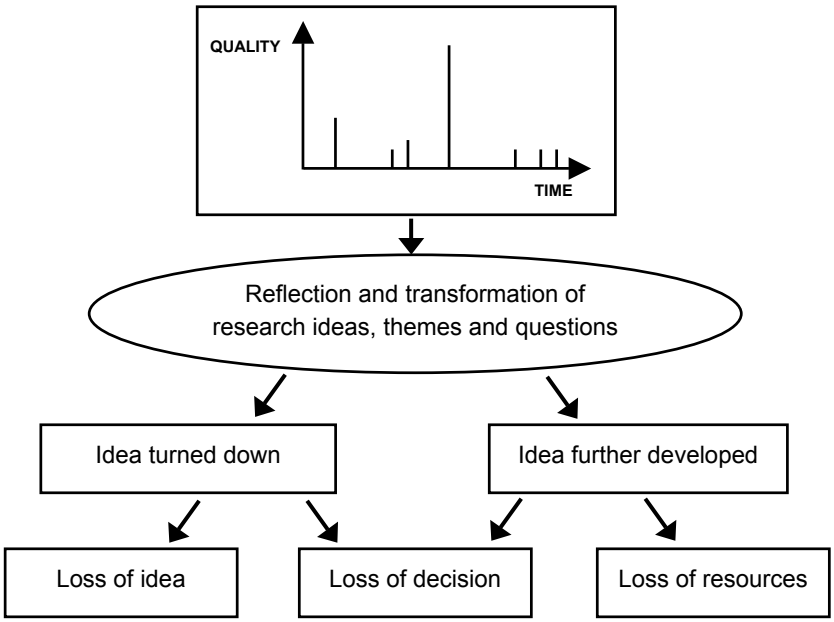
The next step is reflection and transformation of the initial ideas into explicit forms that can be presented and discussed, and further developed or turned down. The individual researcher as well as a research team can perform this initial reflection. At this point it is not known whether the idea is an idea that ultimately can be developed into important knowledge or not; i.e., the embedded quality is still unknown, and the decision is therefore based on uncertainty. The possible outcome of this selection process is seen in Table 4-1.

Table 4-1: Outcome of primary reflection and transformation - primary decision/selection process

		Embedded quality of the idea	
		High embedded quality of the idea: Idea could (have been) develop(ed) into important knowledge	Low embedded quality of the idea: Idea can not be developed into important knowledge
Decisions that can be made	Idea further developed	Right decision	Problematic decision - loss of resources that could have been used to develop other ideas
	Idea turned down	Problematic decision - loss of important idea	Right decision

This process is also seen in Figure 4-2.

Figure 4-2: The primary research input and the first selection process



The initial ideas, themes and questions are discrete, random, and dependent on the knowledge and research interest of the individual researchers. The quality of the primary reflection and transformation is dependent on the knowledge embedded in the researcher presenting the idea and the quality of the initial feedback the researchers get on the idea, i.e., the organisational knowledge base and environment.

In order to have a constant flow of relevant ideas in a research environment the management needs to ensure that at least some of the researchers are capable of inventing ideas, themes and questions. This may be done at the point where the researchers are offered positions as well as in ongoing internal feedback to the individual researcher's performance. This might be seen as the first managerial problem.

The next managerial problem is to optimise the number of right decisions when allocating resources such as manpower and labs, etc. to ideas or themes. Creating well-functioning feedback mechanisms in the organisation is one way to support this. Supporting the working environment, team working, etc., can be an issue just as the creation of formal decision-rules. Therefore, the amount of knowledge embedded in the researchers as well as in the organisation, i.e., the researchers, their qualifications, and the knowledge flow and feedback mechanisms within the organisation, can be regarded as input to the performance process. After the primary selection process of research ideas within the organisation, the next decision is the selection of the ideas that the organisation will promote strategic: what ideas should be developed into research projects that the organisation will support. This can as the primary selection process, be described in a table with possible outcomes as seen in Table 4-2.

Table 4-2: Outcome of secondary selection process/decision - idea turned into research project

		Embedded quality of the idea	
		High embedded quality of the idea: Idea could (have been) develop(ed) into important knowledge	Low embedded quality of the idea: Idea can not be developed into important knowledge
Decisions that can be made	Idea turned into research project and supported	Right decision	Problematic decision - loss of resources that could have been used to develop other ideas into projects
	Idea not turned into project or project turned down	Problematic decision - loss of important idea/project	Right decision

But a project supported within the research environment is not a project funded. The funding decision by the internal research management is a double decision: first it must be decided if or if not the project is worth supporting as seen in Table 4-3, second it must be decided how the fund shall be raised. Most public research institutions have possibilities to support some projects by internal means and research projects are normally partly financed internally; e.g., the researchers can use the laboratories or computers, some of the researchers might be on the payroll of the university while writing the initial proposal, etc. If possible, the research managers will seek external funding of a research project for two reasons:

1. The external funding adds resources to the research unit.
2. It provides an extra quality check of the decision: when projects pass an external programme committee, they will pass an external valuation.

In some cases managers (or collegial bodies) can choose to support projects that have failed to achieve external funding. This can be the case where the sources for external funding are (extremely) limited, but the project is essential to the research strategy in the environment. However, often projects that have failed to raise external funds are turned down.

The actual form and presentation of the research project, as well as the quality of it, is dependent on the knowledge base in the organisation. If the organisation possesses experience in handling external funding and knowledge on funding procedures and priorities, the probability of getting external funding for a project is

larger than the probability for a similar project from an organisation without this knowledge.

This is so because an organisation that possesses knowledge on the demand for research from industry as well as the public sector is more likely to seek funding of projects in the right place and time, and it is more likely to present the projects in such a way that it is funded. It can also be assumed that projects that fit possible needs of industry or society are more likely to be externally financed if it is clear to the external decisions makers that this is the case. At this point one could argue external managers partly take the 'managerial funding decision': funding it is (partly) decided by research councils etc. and is therefore also dependent on their strategy.

The demand for research seen form the perspective of the research manager at the research institution is demand from the public sector as well as demand from the private sector. The knowledge of the demand for research or the impact that research managers can have on demand is essential for managers that are to be successful in the long run. The impact on demand can be accessed by knowledge exchange between the research managers and industrial managers as well as knowledge exchange within the political system when research managers achieve influence on the research policy.

The outcome of the funding process can be described as with the other decisions/selection processes in a table as seen in Table 4-3:

Table 4-3: Outcome of funding decision/selection process

		Embedded quality of the idea	
		High embedded quality of the idea: Idea could (have been) develop(ed) into important knowledge	Low embedded quality of the idea: Idea can not be developed into important knowledge
Decisions that can be made	Research project funded	Right decision	Problematic decision - loss of resources that could have been used to fund other projects
	Research project not funded	Problematic decision - loss of important project	Right decision

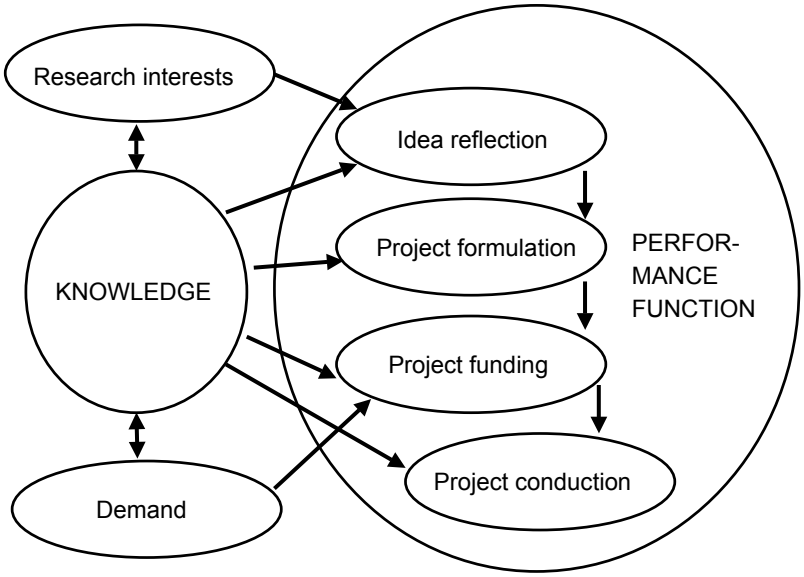
After the project is funded it has to be *conducted and finished*. At this point it can be regarded as a success if it provides important new knowledge; or it can be regarded as a failure: useless knowledge, or just not finished at the right time. But in any case it may provide a lesson the local research environment and maybe others can learn from.

The performance function of research management is found in the flow between the inputs and the probability of development of important knowledge, i.e., success. The performance function is seen in Figure 4-3. (A formal description of the model is found in Appendix 3).

As seen in the figure, organisational knowledge plays a core role because *knowledge* has a direct effect on the performance function, i.e., a shift in knowledge level (a shift from one research manager to another) will be reflected in a shift in the performance. At this point this knowledge can be divided into four forms of knowledge:

- Knowledge of the research interests within the organisation.
- Scientific knowledge.
- Managerial knowledge.
- Knowledge of the demand for research within the specific area.

Figure 4-3: The static research performance function



The manager's or the knowledge environment's knowledge of the research interests is knowledge of the single researchers' research interests. A research manager needs to know what interests researchers have for several reasons:

- The research interests themselves are essential to the formulation of new ideas, and knowledge about them is therefore important for the manager when evaluating the probability of reaching strategic goals.
- The knowledge is necessary when specific demand for research is to be connected with the right group of researchers.
- The knowledge is necessary for the manager when (s)he has to decide whether or not the research unit is capable of joining a (collaboration) project.
- The knowledge is necessary when decisions are made for appointing new researchers.

This knowledge on the (other) researchers research interests can be spread throughout the organisation via (research-) seminar, workshops or by the use of an internal research information system. The knowledge can also be archived by systematic interviews of the researchers (once a year, on a number of subjects).

The fundamental scientific knowledge in a research organisation is necessary for the actual performance of the research. This knowledge consists of formal knowledge that might be measured in number of researchers with a PhD within specific areas, number of articles, etc., and informal knowledge that might be measured by mobility, etc.

The managerial knowledge in a research organisation is necessary for the development of the performance. Simple things like appointments have to be made, bills have to be paid, plans have to be made and followed, contracts have to be handled, feedback mechanisms have to be supported, and in addition the management of the human resources needs to be in place.

The manager's knowledge on the demand is also important when specific research interests are to be connected with it; and in assessing how new strategies are to be developed. This impact can be indirect when researchers exchange knowledge with persons from industry on both formal and informal ground, or direct, e.g., when researchers formulate parts of governmental research programmes.

Beside the knowledge that includes knowledge on research interests as well as demand, these elements have there own direct impact on the performance function: the research interests generates the ideas and the demand is in some cases essential for the funding decision. One could argue that the manager's

knowledge of the research interests and the demand for research is the element that connects the two. It is not enough that researchers have important ideas, the right ideas need support, and it is not enough that research within specific areas and on specific items can be funded research projects have to be defined.

As argued, the performance function is a function of *the probability of making the right decisions* at all of the following levels:

- When reflection on the idea is conducted.
- When the project is formulated.
- When the project is supported or refused.
- When the project is funded.
- When the project is conducted.

It might be different researchers or teams that are responsible for the decisions at the first two levels, and it might be other research teams or managers that take the decision to support the project or not. The decision of funding might be influenced by decisions on a political level, e.g., the research policy might focus on a specific issue, meaning that some projects will achieve a higher probability of funding than others. And finally the success of the project is dependent of the capability of conducting the project, and other researchers than the ones that invented the ideas might do this. A large number of researchers might therefore be involved in successful projects, and their work needs to be coordinated. This coordination is as essential for the results as the decisions made at the different levels.

The point in writing a part of the performance function up as a function of a number of *Probabilities of the Right decision* is that if the probability is 0 at any point in the number of decisions it will result in a probability of creating new knowledge at 0, regardless of the quality of the idea, the capability to conduct research, the embedded knowledge in the organisation, or the other probabilities. Or said in another way: if there is a *weak point* any place in the line from the primary reflection to the capability to conduct the research, the research idea will not end as a successful research project.

The probabilities at every decision-point are influenced directly by the research management; a change in research management will therefore change the probability of creating new important knowledge. These critical points with relation to the research management are:

- The formulation and decision according to strategic plans,
- The development of the research environment in such a way that feedback mechanism is optimised, and
- The building of the 'right' research team: a team that possesses the capability of creating and developing new ideas, of presenting the project the external reviewers, as well as a team that possess capability of fulfilling the project to the end, i.e., to the development of new knowledge.

This change in research performance-function can be compared with technical changes in the production-function in a model of growth with technical changes.

In Romer's growth model with technical change (Romer, 1990) technical change is "*improvement in the instructions for mixing together raw materials*" and "*instructions for working with raw materials are inherently different from other economics goods*"; these instructions are transferable knowledge, and can be given again and again. Romer uses the phrase *non-rival good* to describe technical changes, where purely non-rival goods have the property that its use by one in no way limits its use by another. By definition public goods are non-rival, and one could say that Romer therefore treats research knowledge as a public good. The model is addressed to analyses of production at the national level.

A model with a performance-function within the research sector in the Romer-model can then be regarded as model within the model where changes in the performance induces technical changes.

4.2 The Dynamic Research Performance Function

Research performance function is not a static function it is dynamic, i.e., dependent of prior experience. The most important issue here is that the outcome of prior research has an influence on future research in at least three ways:

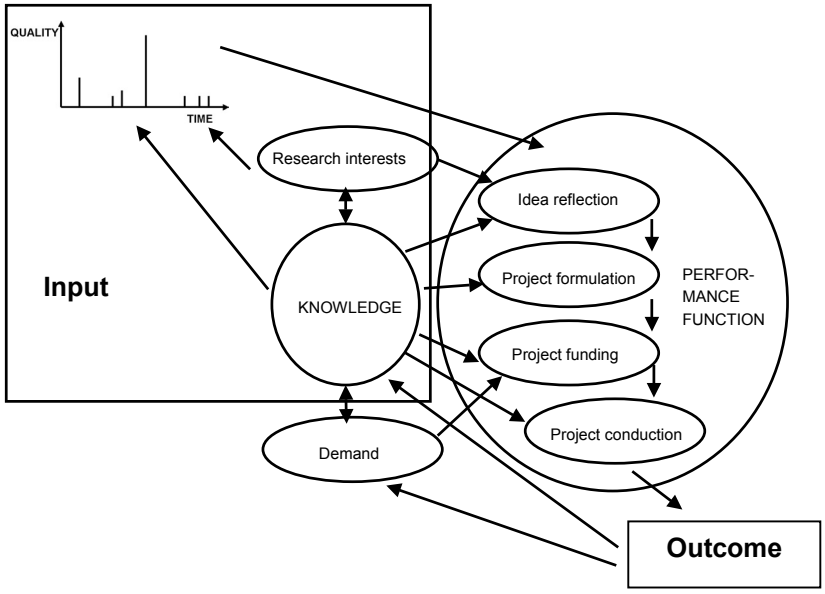
1. Prior research adds knowledge directly to the knowledge base (of the individual, the organisation, and other researchers) because research is knowledge production.
2. The research process adds knowledge on performing research, to the researcher as well as the organisation; an effect know as ‘on-the-job-training' in a labour market context, and
3. Prior research results will effect the funding decisions of future projects.

Research in one period can then be considered as an input in the next period in at least two ways:

1. Explicit research outcomes such as articles, patents, books, etc. are input to the research sector as well as to other sectors in the economy, i.e., an input that can be used by a number of organisations. Change in this kind of research knowledge is like the technical changes in the Romer model for *non-rival goods.*
2. Explicit research outcomes kept within the organisation as well as the informal experience from the research process embedded in the researchers and the organisation where the research were conducted can be seen as input in specific research organisations. This specific form of input exists at all levels in the performance function.

The dynamic performance function is shown in Figure 4-4. The double arrows are immediate feedback; other feedback mechanisms are the knowledge circle, *knowledge* and *research interests* to the *initial ideas,* and the knowledge circle from outcomes via demand and knowledge and back into the performance function.

Figure 4-4: The Dynamic Research Performance-function with input, output, and feedback mechanism



As seen again demand for research plays a central role. Information on demand might not only channel resources to the research sector from other sectors; it might also transmit general research outcomes as well as other kinds of information back to the others sectors and in this way support growth in society. Demand and knowledge of the demand is one issue among others in research management, and focussing on demand might cause a (discrete) rise in the growth.

The embedded knowledge is the core issue if the outputs of the performance function are to be affected by changes in management. One important issue is therefore active knowledge management that supports the growth of the knowledge base within the research environments.

Consequently, a successful research manager in the long run is a manager who responds to changes in the *research interests* of the researchers as well on changes in the surroundings, i.e., demand in such a way that the probabilities of the right decisions are as large as possible. This requires a high degree of scientific knowledge, networks and managerial skills.

4.3 The Economic Perspective of research performance Model

If the above mentioned model of research performance is entered into a three sector model with technical changes like the one developed by Romer (1990) some new perspectives of the model arise.

The three sectors that appear in the model by Romer are (see Figure 1-5):

- The research sector that uses human capital and the existing stock of knowledge to produce new knowledge labelled *new designs* (the focus in discussions of research management).
- The intermediate-goods sector that uses the designs as well as forgone output to produce producer's durables (capital).
- The final-goods sector that uses labour, human capital and the set of producers durables (consumer goods).

There are two main differences between the elements of the Romer model and the performance function described above:

1. The knowledge is not only explicit non-rival knowledge but also knowledge that is embedded in the research organisations.
2. There is a feedback mechanism from productions sectors to the research sector via the (knowledge of) demand for research.

The main result of this is then that changes in the research sector will affect the rest of society regardless of the kind of the changes, e.g., changes in inputs or changes in the management of the research sector.

The model of research performance function is based on an empirical study of research management and has not (yet) been tested. The largest problem in testing the model is measurement of the knowledge base. One solution of this problem could be the use of latent variables.

In any case: if changes in the performance function have an effect similar to the *endogenous technical changes,* it is problematic to use the R&D expenditures directly in empirical functions describing the effect that R&D has on society as it is done in studies based on simple Cobb-Douglas functions.

5. Changes in Research Management at Danish Universities and Government Research Institutes

Research management within the public sector has been widely discussed in Denmark as in other European countries. The major parts of the public research sector in Denmark consist of universities and Government Research Institutes (GRIs) and these organisations are therefore the main objects of this report; other parts of the public sector are hospitals (outside the university sector), museums and private non-profit organisations. Within the last decade several changes have taken place in the management of universities and GRIs. Some of the changes have been based on changes in the law and the direct state funding (called basic funding) of the research, i.e., changes imposed by the politicians; others were results of strategic planning on the institutional level; and some changes were the result of changes in the surrounding society.

A number of initial models have been used as inspiration for this study but as seen afterwards the initial models, of which some are described in section 1.1 and 1.2, either dealt with parts of the total chain from *initial idea* to *important knowledge*, or focussed on one *level* within the management of research: either the management of research projects, management of research departments or institutions, or the research policy level. One main issue of the Research Management under Change (ReMaC) therefore became the formulation of an overall model of Research Management that could be wider developed. Such a model is presented in section 4.

In the beginning of the 1990s, the unique Danish management system designed in the 1970s at the universities was slightly changed: the management was still based on an election system among researchers, technical staff and students, but now the decision rights were moved from the elected collegial bodies to the elected managers and the collegial bodies were reduced to advisory boards. At the same time the group of persons that could be elected to central managerial positions were reduced to full and associate professors. In the mid-90s all 11 universities were state universities, they followed the same law regardless of their size, all had PhD-studies, and all research personnel where appointed according to the same rules, though the universities were and still are very different. Within the last month (May 2003) the law that regulates the Danish universities has been changed, these changes are so new, that it is still guesswork to predict the effects of them. But one major change will occur: the election system will partly disappear and the coming heads of universities and departments will probably be appointed.

In the beginning of the 1990s, some of the government research institutes were integrated parts of the ministry they were connected to, some of them were managed according to specific laws, some of them had boards, and they were in general managed accorded to a large variety of rules. In the mid-90s, the government research institutes were reformed, and the rules for the GRIs were standardised. The reform included a board for most of the GRIs and a new (job-)position structure for the researchers was put forward in order to support the mobility between universities and GRIs: the new structure were based on the system at the universities.

These changes as well as the structures at universities and GRIs are described in section 2. It has been announced by the government that the structure of the GRIs will be changed; one major change may be that researchers in the future will be (more) involved in teaching at university level. It has been decided that a number of the GRIs will be integrated into the universities and others will have to merge, but the final reform is still to come.

During the study, a number of case studies were conducted with the actual management in focus; some of the cases are presented in section 2 and in section 3. The case studies as well as the studies of the structure of the public research system in Denmark revealed a complex picture where changes in one part or level of the system interacted with other parts; consequently the study points at a lack of an overall model. This model should include the total chain from *development of research ides* to the *final transformation to other parts of society* as well as the model should describe the *critical points* managers of research face at different levels. Such a model is presented in section 4, where to core aim of research management is presented as:

The aim of research management is improvement of the performance function that transforms the constant flow of different inputs to research performance process into new important knowledge.

The basic idea in the model is that initial ideas have to be transformed into important new knowledge before society can gain from the research. This transformation can be more or less smooth; it can be stopped, it can be supported, and in general it is uncertain and it might take years before useful results occur. This transformation of the initial ideas into useful knowledge is called *the research performance function*.

The performance function is dependent on the amount of knowledge that researchers and managers in the environment possess. Knowledge can be separated into four parts:

- Knowledge of the research interests within the organisation.
- Scientific knowledge.
- Managerial knowledge.
- Knowledge of the demand for research within the specific area.

This knowledge is achieved in a dynamic system involving education, feedback mechanisms, etc.

The critical points in research performance model, i.e., the points where the managers have to take 'the right decision' are the following points:

- Decision to support development of ideas from loose research ideas to formulated and reflected ideas.
- Decision to support the project formulation.
- Funding decision.

The actual managers might differ at different levels or points: the decision to go on working with an initial idea might be taken at the individual level or within a minor research group; the decision to support the formulation of the project might be taken by a research manager at another level and the funding decision might be taken at different levels: at the local institution/the local department and at a programme committee. The wrong decision at just one point will cost either resources or loss of important ideas. The managerial problem seen from the perspective of the performance function is that decisions at all levels have to be coherent.

The case studies as well as the surveys showed that the Danish research environments differ in a number of ways: some are dynamic, characterised by mobility, teamwork, many feedback mechanisms and active managers; others suffer from the lack of a positive social and scientific environment. A large number of university researchers argued for a change of the managerial system when commenting this aspect in a survey; but another large group resists any changes.

The research performance function needs to be further developed and tested, and further research has to be performed. One possible test of the model could imply a study of the effects of the reforms made in 2003.

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Software used in analyses

SAS/Base, SAS/STAT version 6.12 and 8.1 [General quantitative analyses, Log linear analyses, General linear model analyses, Factor analyses]

PRELIS version 2 & LISREL version 8.20 and 8.30 [Latent structure analyses]

QSR N4Classic version 4.0 [Qualitative analyses]

Appendixes

Appendix 1.
Models behind the Attitude-questions

The models behind the attitude-questions in the case studies as well as the study on university researchers were built on the experience from the study of the government research institutes in 1998. The presentation of the models in this appendix is therefore focussed on this study.

The attitude questions in the *Government research institute survey in 1998* were designed to describe the management in general in each GRI as well as the difference between the institutions.

The statements were made according to a number of assumptions:

- **The researcher as a worker.** Ordinary labour market theory suggests that the main reason for being on the labour market is connected with the utility of the wages, – and that a person will accept a job if the utility of the wages exceeds the discomfort of working. This assumption was combined with the assumption that researchers (as any other worker) might go to work because they were interested in the work – in the process of working as a researcher, using the concept *process utility* (Langberg, 1999). This assumption was investigated directly by attitudes *I'm very interested in the content of my work* and *I have a dream job*', the assumption seemed to be correct. This assumption is connected with an assumption of importance of **research interest**. No questions were added about wage because of the stiff Danish wage system.
- **Government research institutes can be regarded as other organisations.** As employees researchers are a part of their organisation in the same way as other employees. They share conditions and restrictions that are consequences of (or the lack of) human resource management in the organisation. They are part of the organisation as individuals as well as a group with special terms, e.g. often considered more powerful than other groups. It was assumed that the relation to the nearest leader was as important as the overall personnel policy seen from the perspective of the individual researcher.
- **The researcher's production is a production of knowledge.** As showed in Table 2-5, researchers at government research institutes have a number of different activities at work. One part – the research – can be seen as *production* of knowledge, the rest as *use* of knowledge. Research

institutes in Denmark - as in other countries – have worked with measuring research and development in order to evaluate the performance of the institutes. One well-known measure is the number of articles per researcher; others are citation index and patents. However, the production of knowledge and the use of knowledge can be and are often closely connected by feedback mechanisms. It was assumed that researchers as well as management focussed more on the research than on the use of the research, because one – and to the individual researcher a very important - difference between researchers and other academics is, that other academics are users and not producers of research. On the other hand, the history of many of the institutes showed that the reason for establishing the institute was that 'someone' (a department, a group of politician etc.) wanted knowledge e.g., research to use. A number of statements attempted to catch information on this issue.

- **The change in position structure from 'ordinary governmental structure' to 'university structure'.** In 1997 a government regulation changed the employment structures of the research staff at the Danish Governmental Research Institutes: all researchers at the GRIs had to face new roles, and these new roles were more like the roles of the researchers at the universities. This change was still discussed at the institutions while we were making our study, and some managers and researchers claimed that the researchers felt that the change would cause researchers to leave the institutes. Others claimed that the change only had a significant impact on institutes doing substandard research, and that the GRIs needed the change.

The rest of the statements focussed on research, views on professional life as a researcher and on management.

All statements were analyses for differences dependent on age, gender, education, and position (in some cases also other background data) in models with and without interactions. Since the study was *explorative* a number of pictures were made. One picture was based on a simple factor analysis, others on LISREL-models (Kallehauge and Langberg, 1999). The statistical methods used were mainly general linear models (regression model with dummies) and log linear models. The latent-model-questions were analysed by factor- and LISREL analyses. In general the statistical methods were used **as tools** with emphasis on p-values, F-values, in the case of LISREL estimations GFI and AGFI were used as guidelines. GFI measures the difference between the estimated value (of the correlations-matrix) and the actual one, and can be regarded as fit-measure similar to the R^2. AGRI is an adjusted fit-measure similar to the adjusted R^2 as seen below (Langberg, 1999).

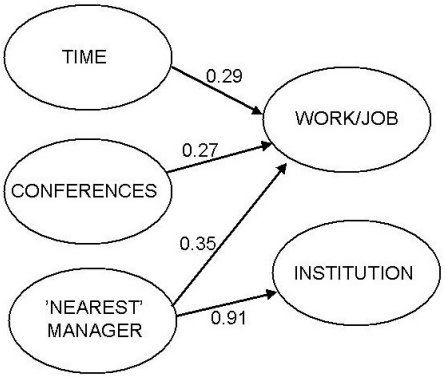
$$GFI = 1 - \frac{TR((\hat{\Sigma}^{-1}(S-\hat{\Sigma}))^2)}{TR((\hat{\Sigma}^{-1}S)^2)} \quad AGFI = 1-(1-GRI)\frac{N(N-1)}{2*df}$$

$$R^2 = 1 - \frac{\sum \hat{e}^2}{\sum (y-\bar{y})^2} \qquad R_a^2 = 1-(1-R^2)\frac{N-1}{df_e}$$

All together, the responses to the statements gave an amount of information about the different institutes as well as overall pictures of the institutes and the researchers.

Among the LISREL-models are a number of sub-models such as the one seen in Figure A1-1. The figures are so-called gamma-values that can be interpreted as correlations (with the max value 1). All the LISREL estimations have been based on poly-choric correlations, and ML has been used.

Figure A1-1: A descriptive model of relations between latent attitudes at Danish government research institutes 1998.



The latent variable WORK/JOB is measured by three manifest variables: *"I'm very interested in the content of my work*" seen in Figure 3-1, "*I have a significant influence on planning my work" ,* and *"I have a dream job"*. The variable INSTITUTE (management at the institute) was also measured by three statements: *"The institute has a clear personnel policy"*, *"The managers of the institutions are concerned about job security"* , and *"The conditions for collaborative work at the institute are good"*.

In the same way three exogenous variables were constructed by the use of a number of questions on attitudes (manifest variables). TIME measured the actual use and allocation of time; CONFERENCES were measured by two statements that were regarded as a measure of external professional contacts, and MANAGER measured the relation to the 'nearest' MANAGER, i.e., at large institutions the nearest manager would be the program manager and at minor institutions it would be the director.

It was assumed that TIME, CONFERENCES and MANAGER all had an impact on how the individual researcher regarded the actual WORK/JOB. It was also assumed, that MANAGER had a direct impact on WORK and that there was a direct connection from INSTITUTION to WORK. The model estimates are seen in Figure A1-1 and some of the *fit-values* are seen in Table A1-1.

The LISREL models in this study are explorative, so no tests are reported. The model is regarded as a fairly good descriptive model if GFI and AGFI are over 0.75 and if the critical N is over 100.

Table A1-5-1: Goodness of Fit statistics for a descriptive LISREL model at Danish Government Research Institutes 1998

Goodness of Fit	Value
GFI	0.89
AGFI	0.86
Critical N	153

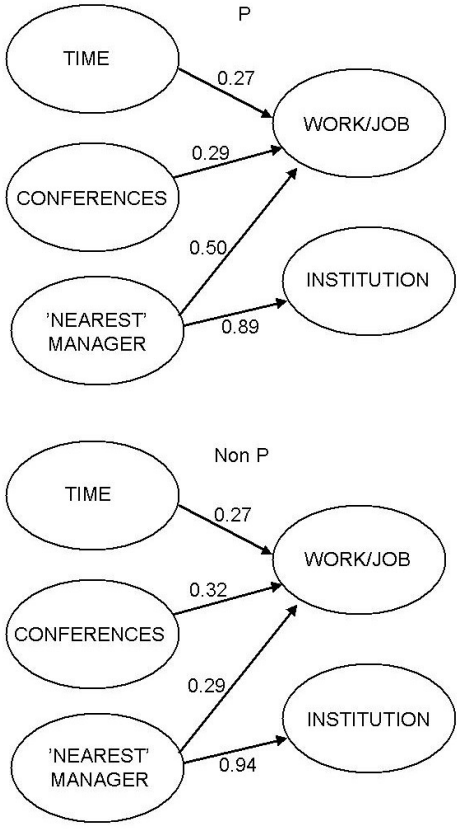
While working with the survey it became clear that the institutions could be divided into two major groups: the institutions where the director had the scientific qualifications that matched the qualifications of a full professor (P) and the others where the director with *management skills* (non P); an information archived by the qualitative interviews of the directors as well as the board members. Information on the director qualifications where then added to the dataset. The difference in attitudes were then analysed in different models where one was a model explaining the difference by age, gender and director-qualification.

Attitude = f(age, gender, director’s qualification)

The results were that a much larger part of the deviation could be explained by the director qualification than by age, and that practically no difference could be explained by gender at all.

Later, the attitudes were analysed in several LISREL models; one example is the sub-model estimated as seen in Figure A1-2. The estimates of the model based on researchers employed at institutions with P-directors are marked P and the other Non P. In Table A1-2 the goodness of fit is shown for the models.

Figure A1-2: Descriptive models of relations between latent attitudes at 'P' and 'non P' Danish government research institutes in 1998



As seen, the impact from the NEAREST MANAGER to WORK/JOB differs in the two situations, the impact is larger when the director is a high level researcher. This can be interpreted in at least two ways: either the director with the *management skills* will use a number of strategies in personnel management, and as a consequence the 'nearest manager' is not as important as in a more university-like structure, or the nearest manager is more visible when the director is

a high level researcher, because the ‘high level research-directors’ more often has ‘high-level-researchers’ as head of departments – and they (the nearest managers) are therefore relatively more important to the individual researcher.

But as seen in Table A1-2 the model based on the P is rather weak, the critical N is below 100 and AGFI is 0.76 - this points at a large variance within the P-group.

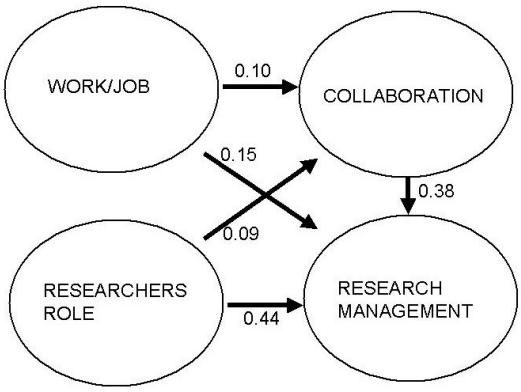
Table A1-5-2: Goodness of Fit statistics for two descriptive models of relations between latent attitudes at 'P' and 'non P' Danish government research institutes in 1998

Goodness of Fit	Value in P-model	Value in Non-P-model
GFI	0.83	0.89
AGFI	0.76	0.85
Critical N	84	145

The model behind the attitude questions in the survey on *researchers at the Danish universities* were based at the same assumptions as the model in the survey to the researchers at the GRI, the experience from the study of *Forest and Landscape* and a number of questions designed to focus on research management.

The initial model is seen in Figure A1-3.

Figure A1-3: The initial model of relations between latent attitudes at the Danish universities 2000/2001



The parameters in initial model converged. The fit-statistics of this model is seen in table A1-3.

Table A1-5-3: Goodness of Fit statistics for the initial LISREL model at Danish universities 2000/2001

Goodness of Fit	Value
GFI	0.81
AGFI	0.77
Critical N	112

Some of the questions regarding *collaboration* are seen in section 3.1.2 where the issue is analysed.

Appendix 2. Same words - different meaning

The concepts/words used to describe structures at Danish and other European Universities differs in a number of ways. In the text I have tried to avoid concepts that can be misunderstood. In this appendix the most common concepts with different meanings is described.

Head of university - rector

The Head of Danish and a number of other European Universities is called *rector*. Until today (April 2003) the Danish rectors are elected by and between full and associate professors at the university for a four-year period. The university reform introduces that the future rectors is to be appointed.

A *rector* in England is a person in charge of a parish, i.e., a priest; but he/she can also be head of a university collage.

The Latin word *rector* can be translated with director

The head of some universities colleges (like Trinity Collage, Dublin = Dublin University) is called *provost.* The provost at Trinity is elected for ten years.

A *provost* can also be a head of a Scottish district council or the head of a chapter in a church.

The word provost is connected to the Latin word *praepositus* that can be translated with director.

The directors of Danish government research institutes are appointed by a board. These directors can be (former) researchers.

The university directors in Denmark are neither elected nor a scientific staff member, he or she is head of the administrative staff and appointed by the rector.

Faculties

At Danish universities as well as in a number of other countries *faculty* is a section of the university e.g., the Faculty of Humanities, the Faculty of Social Science etc. These sections/faculties are headed by a Dean, e.g., the Dean of Humanities, the Dean of Social Science etc. The Danish Deans are elected in the same way as the 'Rectors'. A section/faculty in Denmark consists of a number of departments.

At a number of universities outside Denmark 'faculty' is used to describe the scientific staff within a department or school. This is the common use of the word in

the U.S. At such universities deans may be chosen to have responsibility of special areas, e.g., a Dean of research, a Dean of education etc.

A dean can also be the head of a chapter of a cathedral

Consistory, senate, councils
The overall managing councils of Danish universities are called konsistorium (consistory) in Denmark. They are headed by the *rector*.

A consistory is a church tribunal, and therefore 'konsistorium' is often translated with 'senate', because 'senate' is used for the governing body at some Anglo-Saxon universities.

But the 'senate' is also used for the governing upper body in some countries i.e. in USA.

The supreme council in the ancient Rome was labelled 'senate'

Appendix 3. The Performance Function

The relations of the static research performance function, seen in Figure 4-3, and the dynamic research performance function, seen in Figure 4-4, can be written out with the use of symbols as seen below.

The Static Research Performance Function
The probability of developing of important knowledge *P(DIK)* is a function of

- A function that describes the research environments capability to **c**onduct research products *F(C)*
- The probability of taking the right decision when the project is to be **f**unded *P(F)*
- The probability of taking the right decision on whether or not to transform the initial idea into a **p**roject *P(P)*
- The probability of taking the right decision on transformation of the initial idea into an explicit idea during initial **r**eflection *P(R)*
- A function that describes the **q**uality of the **i**nitial idea, *QI,* the random function of the embedded quality of the initial idea, theme or question and the initial resources *I*. This function is then written *F(QI,I)*

This can be written as:
$P(DIK) = [F(C)*P(F)*P(P)*P(R)]*F(QI, I)$
where
$[F(C)*P(F)*P(P)*P(R)]$ is the performance function

The performance function is dependent on the embedded knowledge, *EK,* at a number of levels since the underlying functions are functions of it: *F(C)* is a function of the embedded knowledge in the organisation *EK* and: $F(C)=f_C(EK, QI)$, etc. as seen below.

$F(C)= f_C(EK, QI)$
$P(F)= f_F(EK, D),$
where D is the demand from the research sector, the public sector in general, and the private sector $D=f_D(D^R, D^{Pub}, D^{Pri})$
$P(P)= f_P(EK, QI)$
$P(R)= f_R(EK, QI)$
$F(QI,I)= f_Q(EK, QI, I)$

The embedded knowledge itself is a function of the scientific knowledge EK^S, as well as the managerial knowledge, EK^M
$EK=f_K(EK^S, EK^M)$

The simplest way to change the outcome in the static model mentioned in Equation 1 is adding a difference in the initial resources or input in the organisation, e.g., difference in number of researchers that will have an influence on the embedded knowledge:

$P(DIK) + \Delta[P(DIK)] = [P(F)*P(P)*P(R)]*F(QI, (\Delta+1)I)$

This difference will then change the probability of creating new important knowledge, *P(DIK)*. A larger amount of initial resources will lead to a larger *P(DIK)*. But a change in the performance function as seen below might have the same effect: if one of the probabilities are low to a start a minor change might even have a large impact.

$P(DIK) + \Delta [P(DIK)] = (1+ \Delta) [P(F)*P(P)*P(R)]*F(QI,I)$

The Dynamic Research Performance Function

$P(DIK_t) = [F(C_t)*P(F_t)*P(P_t)*P(R_t)]*F(QI_t, I_t)$

where

$F(C_t)= f_C(EK_t, QI_t)$

$P(F_t)= f_F(EK_t, D_t)$,

$D_t=f_D(D^R{}_t, D^{Pub}{}_{,t}, D^{Pr,i}{}_t)$

$P(P_t)= f_P(EK_t, QI_t)$

$P(R_t)= f_R(EK_t, QI_t)$

$F(QI_t,I_t)= f_Q(EK_{t-1}, QI_{t-1}, I_t)$

and

$EK_t = f_{EK}(EK^M_t, EK^S_t) = f_{EK}(QI_{t-1}, D_{t-1}, EK^M_{t-1}, EK^S_{t-1}, EK^M_{t-2}, EK^S_{t-2}, EK^M_{t-3}, EK^S_{t-3}.....)$

A quantitative empirical study of the dynamic research performance function would have to use indicators such as:

- The embedded knowledge EK_t. This could be indicated by a number of variables like:
    - Number of researchers
    - Researchers' education and experience
    - The managers' education and experience
    - Type of management
- The probability information available like information on funding P(F)
    - External grants - success rate
    - Participation in networks

And then the problem has to be reformulated in such a way that it can be estimated eventually by the use of latent variables (in LISREL models).

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