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Factors influencing the effectiveness of R&D efforts in the Nordic countries

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TemaNord 2007:553

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TemaNord 2007:553

ISBN 978-92-893-1533-3

Print: Ekspressen Tryk & Kopicenter

Printed on environmentally friendly paper
This publication can be ordered on www.norden.org/order. Other Nordic publications are available at www.norden.org/publications

Printed in Denmark

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Nordic cooperation

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Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

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Terms of Reference

This project is performed for the Nordic Council of Ministers, acting through the Danish Ministry of Finance. The task is to describe factors which determine the effectiveness of public and private R&D efforts.

The project has been carried out from 1 March 2006 to 30 September 2006. The results are delivered in the form of a report.

1. Introduction – Part one

Throughout the last 50 years, the understanding of the role of R&D for the development of society has been much expanded. After the Second World War the importance of scientific development to society became widely recognized. Scientific breakthroughs were perceived to have played a major role in determining the outcome of the war as well as in bringing new products to the market. For example, Bush (1945) argued in a report invited by the White House that science provided an endless frontier and science should be heavily subsidized by the government.

Since then, government support to research and development (R&D) has increased throughout the developed world, and so has the private sector's expenditure on R&D. A relatively recent example of the increased recognition of the importance of R&D is the European Union's objectives to increase the R&D expenditure of the European countries to 3 percent of GDP by 2010 – a third of which should be public expenditure.

To inform public decision whether to undertake R&D or to support the private sector's R&D activities – or not to so either - it is useful to analyze to some depth the benefits and costs to society from undertaking or supporting R&D.

There are many studies of private and social returns to R&D. The studies tend to find private rates of return of comparable size to the rates of return for other kinds of capital investment. The estimated social rates of return are generally very high. Taken at face value, the estimates of social rates of return would imply that there is a case for further public investment or involvement in R&D. However, estimates of the rate of return to R&D are in principle valid only for combinations of R&D resource use and value added which have been observed in historical data. For increases in R&D expenditures to levels which go way beyond those observed in historical data, it is necessary to consider whether the personnel and equipment necessary to do R&D are likely to be available.

Hence it is important to consider whether there is sufficient R&D personnel available to perform increased R&D efforts, and how the wage of researchers responds to increasing demand for R&D personnel.

In the following section, an introduction is given to the conceptual framework used. In section 3, a brief review of the literature estimating the private and social returns to R&D is given, followed by a thorough analysis of the short term supply of research personnel in Denmark. Section 4 concludes.

2. Conceptual framework

R&D encompasses a range of activities involved in creating and employing knowledge to develop new goods, services and processes. The OECD (2002) (and UNESCO) defines R&D as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to device new applications. Appendix A contains an in-depth discussion of the concept of R&D. Innovation is an example of an R&D output. Innovation is defined as the introduction in the market of new products or processes. A thorough description and definition of different types of innovation can be found in European Commission (2003).

For the purposes of this project, R&D is considered an input-concept with the relevant output being new knowledge and new applications. The valuation of the output of R&D is central to the overall evaluation of the public sector's policy in the area of R&D. The value of new knowledge and new applications is primarily that they improve the standard of living by increasing the variety of goods, improving the processes by means of which they are produced etc. R&D input is thus transformed into new applications in private companies and public institutions and new knowledge which in turn feed into future innovation.

Evaluating the output of R&D efforts is difficult, because:

- The results of R&D efforts often materialize in a future which is distant from the time at which the efforts take place, or the results come in a non-tangible form.
- The results of R&D efforts often benefit a large but diffuse group of individuals, firms and public institutions.
- The results of R&D efforts often arise in a complex interplay between researchers, R&D institutions, private firms, government institutions etc.

The first point emphasizes the importance of distinguishing between different types of R&D. Basic research is not necessarily tied to any immediate application, and may not give any benefits to society until the distant future (or may never prove valuable at all). On the other hand, experimental development may result in concrete and immediate benefits to society. OECD (2002) and Appendix A discuss these different categories of R&D at some length, and chapter 3 below gives a review of studies of the value of different types of R&D.

The second point relates to the existence of external effects of R&D. That is, the individual, firm or other, which undertake R&D, does not fully take into account the benefits (and costs) to the society as a whole. There are many types of external effects to consider. One important type of external effect is the “standing-on-shoulders” effect, that is, the results of a concrete R&D effort facilitate future R&D efforts. Another type is the “appropriability” effect, that is, the firm or individual, who invests in R&D, will not be able to reap the full gains from the results of R&D – the gains must be shared with consumers, suppliers, employees and others. A third type of external effect is the “business-stealing” effect, that is the gains, which a firm reaps from R&D efforts, may come at the expense of other firms. A more extensive discussion of different externalities associated with R&D can be found in Aghion and Howitt (1998).

The third point stresses the importance of framework conditions for R&D. R&D efforts require the existence of highly qualified personnel, access to sources of knowledge and access to funding and is facilitated by the possibility of obtaining ownership rights over the output of the R&D process etc. A tentative model of the relationship between R&D input and output is shown in Figure 3.1.

A full and original description of the complexity of the innovation process and the actors involved can be found in Gibbons et al. (1994). An in-depth analysis of the importance of framework conditions for R&D efforts and performance is given in Nordic Council of Ministers (2005).

3. The economic return to R&D

The literature on the estimation of the private and social returns to R&D received an important impetus with the recommendations of Edwin Mansfield in 1971 to the National Science Foundation on topics in R&D that required further research. In his recommendation, Mansfield highlighted the need for improvements in R&D data, better price indices, disaggregate analysis of the effects of R&D and many other areas. Since then, the literature on the economic effects of R&D has grown much in both scope and volume.

The literature can be subdivided into a number of subfields, depending on the quantity they seek to estimate, the data and the empirical methods used. A first distinction is between papers which estimate the private and the social rate of return to R&D activities. Within each of these groups one can distinguish between papers which use cross section data and panel data.

3.1 Estimates of the private rate of return to R&D

The private rate of return to R&D is usually estimated by regressing firms' value added on some measure of R&D capital or R&D expenditure.

Wieser (2001) is the most recent survey of the literature on private rates of return to R&D. He surveys 50 studies of the private rate of return to R&D and finds that about half of the studies report statistically significant estimates. Among the significant estimates, the estimated annual rates of return range from 7 per cent to 69 per cent with a mean value of 28.8 per cent. Hall (1996) is an older, but much cited survey of the literature estimating private rates of return to R&D. Hall finds annual rates of return to changes in the R&D capital stock in the range of 10-15 per cent. This indicates that the private rate of return on R&D investment has converged to the private rate of return on other forms of capital investment in the 1980s. However, it is fair to say that there is a large amount of uncertainty associated with such estimates.

A recent study based on Danish data, Graversen and Mark (2005), finds rates of return of to R&D in the proximity of 11 per cent for all Danish firms. Similar results are found by the Nordic Council of Ministers (2006).

The estimated rates of return are different for studies which use cross section data, time series and panel data. Wieser (2001) report the highest estimates for studies based on time series data and the lowest estimates for studies based on cross section data. Panel data based studies find estimates in the middle of the range of estimates. Furthermore, the estimated rates of return appear to be higher in the 1980s than in the 1970s.

3.2 Estimates of the social rate of return to R&D

The private rates of return to R&D thus appear to be relatively aligned with the rate of return on other types of capital investment, including a risk premium. However, various types of externalities imply that there is reason to expect that the social rate of return exceeds the private rate of return.

The social rate of return is estimated in different ways, depending on which externalities are analyzed. Usually the social rate of return is estimated by regressing the growth in one firm on R&D done in other firms. Other firms may be in the same industry or in other industries.

Griffith et al. (2004) report estimates of social rates of return to R&D, which include the effect of R&D activities on the ability to absorb new ideas developed elsewhere. The estimates of social rates of return are calculated for all the OECD countries and range from 67.9 per cent for Denmark over 68 per cent for Sweden and 75.6 for Norway to 95.2 for Finland. These estimates are quite high, but they do not stand out in the literature, which estimates social rates of return. Jones and Williams (1998) contains a survey of estimates of social rates of return to R&D where the reported rates of return range from 71 per cent to 107 per cent.

Even if the estimates are taken at face value, it is important to consider whether one can expect the estimated rates of return to prevail for hypothetical R&D policy initiatives. The estimated rates of return are found within a sample of countries over a period of time, and are in principle valid only for the range of data values observed in the given set of data. They are not necessarily true for levels of R&D investment which are higher or lower than the ones observed in historical data.

3.3 Framework conditions for R&D

To get an impression of whether the estimated rates of return are relevant for increases in the R&D investments it is necessary to consider closely the processes by which R&D input is transformed into R&D output. From a macro perspective, the relationship between R&D input and innovation can be illustrated as in
Figure 3.1 below.

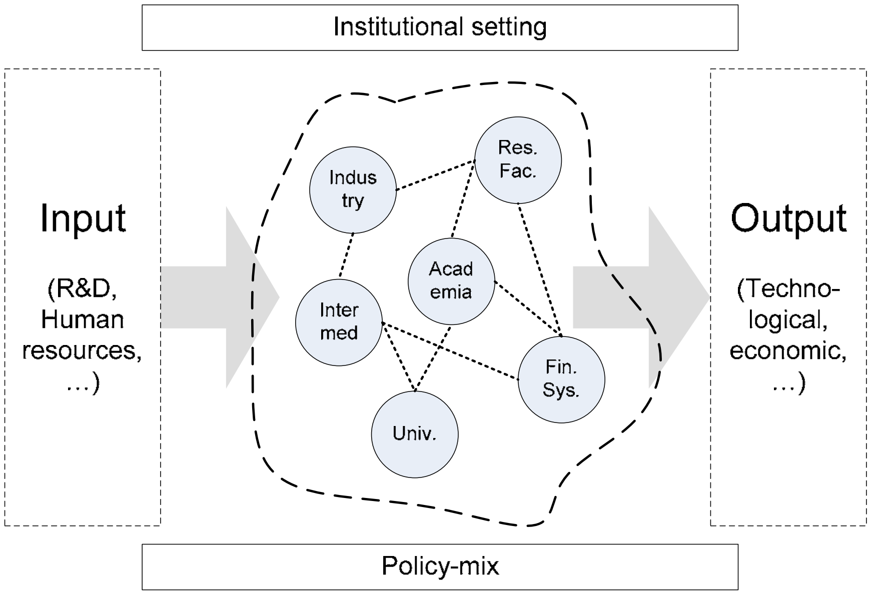

Figure 3.1 Conceptual framework

Source: Rannis (2005).

Input of R&D in the form of equipment and labour is transformed into R&D output in an interaction with society's knowledge resources at universities, academic institutions and other knowledge networks in industry, venture capitalists, public sector knowledge intermediaries etc. The institutional setting encompasses the possibility of obtaining intellectual property rights, the enforcement of such rights and of R&D contracts and the formal possibilities for cooperation and coordination of R&D activities between private and public actors. The mix of public policies in the field of R&D affects both the incentive to do R&D and hence the amount of input, but also the effectiveness of the transformation of R&D input into R&D output. Nordic Council of Ministers (2005) contains an extensive discussion of the importance of framework conditions for the innovative activity in a society.

3.4 The labour market for scientists

The main R&D production factor is personnel. In calculations of R&D capital it is common to include wage expenditures associated with the R&D activities. Hence the response of the wage of R&D personnel to increased demand for R&D personnel is a key factor in evaluating the rate of return that can be expected from future investments in R&D.

This understanding is not new, but has been at the heart of the science policy debate since at least the 1950s, when science became a major policy-topic in the U.S.

It is possible to distinguish between the lines of enquiry into the factors determining PhD enrollment, and into forecasting scientific labour markets. It is noteworthy that no studies have been found of the occupational choice of personnel who have completed education which qualify for employment as a researcher. This is probably because the data for such analyses are not available in many countries for a subdivision of researchers into occupations or a subdivision of the employment in different occupations on educational status.

The literature on the factors determining PhD enrollment is surveyed in Stephan (1996) and in Ehrenberg (2004). Stephan summarizes the findings in 1996 as

- relative salaries in alternative fields affect the supply of graduates in a given field
- draft deferment policy affects supply of graduates in a field
- cohort size affects the supply of graduates
- R&D expenditures affect the demand for graduates by institutions.

The more recent survey by Ehrenberg (2004) highlights that

- financial aid patterns for PhD students affect the time it takes for a PhD to finish.

Some of the most recent studies of the workings of the PhD labour market are Borjas (2006), Freeman et al. (2004), Ryoo and Rosen (2004) and Zucker et al. (2002).

Borjas (2006) analyzes the impact of immigration on the wage of doctorates in the U.S., using the National Science Foundation's Survey of Earned Doctorates and Survey of Doctoral Recipients. Borjas constructs a panel data set covering 5 waves of data from 1993 to 2001. He then employs a combination of fixed effects regression and OLS to find the effect of immigration on doctorate earnings. He finds that a 10 per cent immigration induced increase in the supply of doctorates lead to a wage reduction of 3–4 per cent of competing workers.

Freeman et al. (2004) analyzes the mechanisms behind the drastic increase in the number of U.S. doctorates. They find that most of the increase since 1970 can be ascribed to immigrants taking PhDs in the U.S., but that the entry of women into research also accounts for a great deal of the increase. Furthermore, the majority of the increase has been in less prestigious smaller doctorate programs.

Ryoo and Rosen (2004) analyze the workings of the U.S. labour market for engineers. They use time series data from a wide range of sources including The National Society of Professional Engineers, Current Population Reports etc. They build a structural dynamic model of supply of and demand for engineers and find that the supply of engineers depends heavily on the expected career prospects, that is, the earnings profile of engineers. The demand for engineers depends greatly on the price of engineering services.

Zucker et al. (2002) analyzes the factors determining that researchers move from academia to private firms. They find that the probability that a researcher in biotechnology moves from a university increases with the quality of the researcher as measured by the number of citations, increases as the number of biotechnology firms in the local labour market increases, but decreases as the number of top universities increases.

3.5 R&D occupations

The focus of this part of the report is on the short term flexibility of the labour market for R&D personnel. That is, a group of potential R&D personnel is considered which consists of individuals with R&D qualifications. Within this group the determinants of occupation and wage are analyzed.

Box 3.1 Definition of R&D

R&D is defined by the OECD as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to device new applications. R&D encompasses three subcategories according to OECD (2002): Basic research, applied research and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed at producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. See e.g. OECD (2002) for an in-depth discussion of the definition.

R&D personnel are individuals working with R&D. It is useful to distinguish between researchers and technical staff. OECD (2002) defines researchers in the following way:

Box 3.2 Definition of researchers

Researchers are classified in ISCO-88 major group 2, “Professionals” and in “Research and Development Department Managers” (ISCO-88 group 1237). Postgraduate students at the PhD level engaged in R&D should be considered as researchers. They typically hold basic university degrees (ISCED 5A) and perform research while working towards the PhD (ISCED level 6).

Thus researchers are defined by their occupation or by their formal education.

Technical staff is defined as:

Box 3.3 Definition of technical staff

> Technicians and equivalent staff are classified in ISCO-88 Major Group 3, "Technicians and Associate Professionals".

Box 3.4 Sources of data for analysis of the market for R&D personnel

> The data used for the analysis of this report come from the registers of Statistics Denmark, which have been developed on the basis of public administrative registers. Information on the educational attainment and the age of the entire population stems from the register on education and occupation while information on the entire population's occupational status, sector and industry stems from the register-based labour force statistics. Finally, information on the job function is from the private and public wage statistics.
>
> The period covered is 1997-2003.

R&D personnel constitute only a limited share of total employment in Denmark, as shown in Table 3.1.

Table 3.1 Researchers and highly educated personnel, Per cent of employment plus persons under doctoral education, 2001

	Researchers	Technical staff	Other	Total
ISCED 6	0.26	0.01	0.04	0.31
ISCED 5A	7.97	6.05	4.93	18.95
ISCED 5B	0.37	1.76	2.50	4.81
Other	2.62	7.22	66.27	75.26
Total	11.22	15.04	73.74	100

Source: Register data from Statistics Denmark.

It is slightly surprising that the group "technical" staff has a relatively low incidence of tertiary or doctorate education, as more than half of the group does not hold a tertiary degree. It is also interesting that one in every eight persons with education level ISCED level 6 is occupied with work unrelated to R&D – as defined by OECD.

The group of persons with a level of education corresponding to ISCED level 6, who is not working with research, is mostly working with legislation and management in the public sector.

A closer look at the composition of the group of technical staff reveals that approximately one third of the group belongs to the ISCED category 3C, which encompasses various kinds of craft-education. The impression is hence that a significant share of the personnel working with R&D has relatively little education.

Box 3.5 Definition of R&D personnel

In the remainder, focus will be on researchers with ISCED level 5A or 6, and on technical staff. The reason why individuals with ISCED level 5B are not included in the researcher group is that the educations in the ISCED 5B group are mainly practical in scope, and hence the group of researchers may become too heterogeneous by including these levels of education.

The distribution of employed researchers and technical staff across economic sectors gives an impression of the allocation of R&D personnel on overall types of work. In Table 3.2 the distribution of researchers and technical personnel across major economic sectors is shown. The private R&D sector consists of firms which specialize in the supply of R&D to the rest of the economy. Researchers and technical staff employed by the "other" private sector perform in-house tasks for private firms. The public R&D sector consists mainly of government research institutes, the public higher education sector consists of e.g. universities and university colleges, and other education is mainly primary and secondary schooling. Other R&D organizations are e.g. non-profit organizations which perform R&D for broader societal purposes. The sector "other" contains e.g. researchers and technical staff at hospitals.

Table 3.2. Sector of employment, 2001, per cent

	Researchers	Technical staff
Private sector		
R&D	0.38	0.17
Hospitals	0.03	0.12
Other	25.41	41.92
Public sector		
R&D	1.05	0.53
Higher education	4.51	1.08
Other education	29.46	2.37
Hospitals	5.46	8.91
Other organizations		
R&D	0.28	0.05
Other	33.42	44.85
Total	100	100

Note: Other organizations are either private cooperatives or self-owned organizations. The category "hospitals" includes so-called "doctors' laboratories".
Source: Register data from Statistics Denmark.

The majority of private sector researchers work in the "other private sector" industries. A closer look at this sector reveals that the greatest single industry (10 per cent of private sector researchers) is the consultancy industry in the area of engineering. Smaller groups are ICT services (8 per cent), the medical industry (6 per cent), and accounting and auditing (6 per cent). Otherwise private sector researchers appear to be relatively evenly distributed across industries.

The group of public sector researchers in the “other education” industry consists mainly of employees in the ordinary primary school sector (folkeskole) and the upper secondary school sector (gymnasium).

The group of persons working in the “other private sector” is very interesting in a Nordic R&D policy context, because of the focus on R&D in high-technology areas. All the Nordic countries aim at strengthening their positions in these fields, and it is interesting to analyze the employment structure in the industries which are defined by the OECD as “high-technology”. Tabel 3.3 shows the distribution of employment by industry and occupation. There are several interesting facts in the table. First of all so-called high-technology firms only account for a small share of employment. Second, high-technology firms appear to be only slightly more intensive in researchers and technical staff than the public sector as a whole. Third, the non-high-technology private sector appears to be quite R&D extensive.

Table 3.3 Employment by industry and occupation, 2001, per cent of total employment

	Private high technology	Other private sector	Other sectors
Researchers	0.20	1.93	6.10
Technical staff	0.33	6.02	8.69
Non-R&D personnel	1.13	46.71	28.89

Note: Only individuals aged 16-64 enter into the analysis.
Source: Register data from Statistics Denmark.

The age distribution of the R&D employment is frequently considered to be an important indicator of the future labour market for scientists. An ageing R&D labour force is often considered a serious problem in R&D policy.

Table 3.4 Age distribution of the R&D personnel, 2001, per cent

	Researchers	Technical staff
16-24 years	0.43	4.00
25-34 years	24.93	26.41
35-44 years	28.16	31.38
45-54 years	30.10	26.10
55-64 years	16.37	12.11

Note: Only individuals aged 16-64 enter into the analysis.
Source: Register data from Statistics Denmark.

The greatest share of researchers is found in the age group 45-54 years, and the greatest share of technical staff is found in the age group 35-44 years. This may reflect the career path of R&D personnel: education and post-education training takes a long time, and therefore potential R&D workers do not start doing R&D before they are relatively old. It may also reflect an ageing problem in the Danish R&D sector in the sense that the education and training of R&D personnel have failed to keep up with the ageing of the R&D labour force.

3.6 Mobility of R&D personnel

The mobility of R&D personnel is of key importance for the short run flexibility of the labour market for R&D personnel. If the mobility is high it is likely that changes in R&D policy, in terms of e.g. a focus on new fields of science, can be accommodated relatively quickly by a reallocation of R&D personnel from one field to another.

There are several kinds of mobility for R&D personnel:

- Mobility between occupations: individuals who were working with R&D in one period may be occupied in another area the next period and vice versa:
    a) Inflow of individuals who finish ISCED level 5A education and start ISCED level 6 education, and dropout from doctoral education
    b) Switch of job functions in and out of ISCO-88 group 2
    c) Migration
- Mobility between sectors: individuals who were working with R&D in one sector in one period may be occupied in another sector the next period
- Private/public/non-government organization
- Mobility between industries
- Mobility between scientific fields
- Mobility between geographic regions within the country.

All of these kinds of mobility are important for the flexibility of the market for R&D personnel, and some of the topics are well-researched. However, as Stephan (1996) note, most empirical studies focus on long-run adjustments, and only a few analyze the movements of personnel between fields and sectors.

Inter-regional migration of R&D personnel within a country has also been the subject of much research. Most of the research concerns specific U.S problems, however, as this country is characterized by having a very integrated labour market, but the individual states have a large degree of autonomy in the design of educational policy. Hence the issue of brain drain is a potential problem for individual states which desire to support the education of R&D personnel. This problem is addressed in a recent paper by Bound et al (2001). They find that in the U.S system of higher education the structures are such that there is a positive relationship between the number of students and the number of graduates in a state. This indicates that some of the students which graduate in a state choose to stay and work in the state. However, they interpret the results to indicate that state policy makers have only modest capacity to influence the human capital levels of their populations.

The outflow of personnel from R&D occupations is illustrated in Table 3.5 and Table 3.7. The former table shows the occupational status of individuals who worked in research occupations in 1997. The table shows that about a quarter of those who worked as researchers in a year have left the occupation seven years later. Three quarters of those who leave the occupation of researcher appear to leave the R&D occupation altogether, whereas one quarter switch to become technical staff.

Table 3.5 Occupational status of individuals who were researchers in 1997, per cent of researchers in 1997

	1998	1999	2000	2001	2002	2003
Researcher	91.67	88.45	80.18	76.52	75.79	73
Technical staff	2.38	3.62	4.6	4.9	4.96	6.1
Deceased	0.22	0.24	0.25	0.26	0.29	0.32
Emigrated	0.64	0.58	0.57	0.51	0.41	0.32
Other	5.09	7.12	14.4	17.8	18.55	20.26

Source: Register data from Statistics Denmark.

The individuals who leave research can either be

- doctoral students who drop out of the education and do not find a job function related to research
- people with a research job function who become unemployed, leave the labour force or find a job function which is not related to research.

Regarding the first group, the occupational and educational choices of the group of doctoral students in 1997 can be followed in Table 3.6. It is interesting to note that although a fifth of the doctoral students in 1997 drop out, about half of those, who drop out of the doctoral education, end up working as R&D personnel after all. It is also noteworthy that two thirds of the PhD students in 1997 finish their degrees and work with R&D seven years later. In total some 87 per cent of those who studied for a doctoral degree worked with R&D seven years later.

Table 3.6 Occupational status of individuals who were doctoral students in 1997, per cent of doctoral students in 1997

	1998	1999	2000	2001	2002	2003
Dropout - no R&D	6.07	7.81	10.99	13.09	12.85	12.61
Dropout - researcher	0.78	5.29	7.39	8.83	10.81	11.35
Dropout - technical staff	0.42	0.42	0.84	0.9	0.96	1.26
Continual student	73.93	52.31	31.23	17.6	6.85	4.92
Finished - no R&D	13.81	7.69	10.39	9.73	10.27	3.66
Finished - researcher	4.26	25.35	37.84	48.05	56.1	63.48
Finished - technical staff	0.72	1.14	1.32	1.8	2.16	2.7

Source: Register data from Statistics Denmark.

For the group of researchers who were classified as researches because their job functions belong to the ISCO major group 2, the majority (69 per cent) still work with research 7 years later. 7 per cent have left the labour force, 1 per cent has become unemployed, 11 per cent have become technical staff and 12 per cent have shifted to other types of job. Of the 12 per cent who changed job function, a third became managers.

Table 3.7 Occupational status of individuals who were technical staff in 1997, per cent

	1998	1999	2000	2001	2002	2003
Researcher	2	2.09	2.55	3.12	3.56	4.21
Technical staff	86.76	81.27	64.66	62.28	58.13	56.44
Deceased	0.25	0.25	0.28	0.31	0.32	0.35
Emigrated	0.55	0.46	0.47	0.4	0.34	0.28
Other	10.44	15.93	32.04	33.88	37.65	38.72

Source: Register data from Statistics Denmark.

The entry into the researcher and technical staff occupations is driven primarily by the transition from other types of job into R&D occupations. The entry of students into doctoral education accounts for about 3 per cent of the entry into the researcher occupation per year, as shown in Table 3.8.

Table 3.8 Occupational status 1998-2001 of individuals who were occupied with R&D in 2002, per cent

	1998	1999	2000	2001
Researcher	70.42	79.85	83.46	88.45
Technical staff	6.00	5.10	3.98	2.15

Source: Register data from Statistics Denmark.

The entry of students into doctoral education is important for the R&D of certain sectors, especially the higher education sector, but also for many areas of industrial R&D. U.S experience is that expansions in the number of graduates from doctoral education occur simultaneously with increasing length of time to complete doctoral education and a relative increase in the number of graduates from the less prestigious institutions of higher education, c.f. Freeman et al (2004). This does not appear to be the case for the Nordic countries. The Nordic statistics on doctoral degrees (Norbal) show no marked increase the age of graduation of Nordic PhDs. A note of caution is, however, that the development in the age of graduation is affected by a number of other factors, and the apparent stability of the age of graduation may be caused by the result of other factors which oppose the upward pressure that an increasing number of graduates would otherwise put on the age of graduation.

To summarize, in Denmark a non-negligible share of potential researchers are occupied in non-R&D occupations and could in principle move to R&D occupations. There is also substantial mobility in and out of R&D occupations. The question is: Does it require large increases in wages to move from non-R&D occupations to R&D occupations?

3.7 Researcher wages and occupational mobility

In this subsection the focus will be on the response of an individual's wage to a change in the person's occupation from a non-R&D occupation to an R&D occupation. This illustrates whether an increase in the R&D employment necessary to increase R&D efforts in society can be expected to lead to large increases in the wage of R&D personnel.

This gives an impression of whether the direct private rate of return to R&D can be expected to remain at a level of about 11 per cent in Denmark when the level of R&D investment increases.

The analysis does, however, miss some potentially important indirect effects. It may be that moving labour from non-R&D occupations to R&D occupations drives up wages in the non-R&D occupations, thereby decreasing competitiveness in other sectors which use labour with R&D qualifications.Table 3.9 and Table 3.10 show the results of fixed effects regression of the wages of researchers over the period 1995–2002 for women and men, divided on private sector and public sector employers. The parameter of primary interest is the parameter which captures the wage effect of changing occupation from a non-R&D occupation to an R&D occupation. Fixed effects regression appears to be useful for this purpose, as the individuals of the sample do change occupation relatively often, and auxiliary analyses indicate that the individuals who change occupation do not differ much from those who do not change occupation. Thus, there is a priory reason to expect that fixed effects regression will allow for identification of the wage effect of changing occupation.

The wage regression for female researchers with a PhD is reported in Table 3.9. Overall, the parameter estimates have the expected signs. Small children reduce the resources available for work, and have a significant negative effect on the wage – in particular in the private sector – whereas there appears to be no effect on the wage of having older children. A history of unemployment has a negative and significant effect on the wage. There is the familiar inverted U-shaped relationship between general labour market experience and the wage. There appears to be no significant effect on the wage of changing occupation from a non-R&D occupation to an R&D occupation.

The wage regression for male researchers with a PhD is reported in Table 3.10. For men, having small children appears to have no effect on wages, whereas having older children is positively correlated to the wage. As above a history of unemployment has a negative and significant effect on the wage, and also the familiar inverted U-shaped relationship between general labour market experience and the wage reappears. For male researchers in the private sector, it appears to be the case that they are willing to accept a lower wage in order to change to an R&D occupation. Single men have higher wages than married or cohabiting men.

Table 3.9 Determinants of researcher wage, PhDs, women, 1995-2002, fixed effects regression

	Private sector		Public sector	
	Estimate	Std. error	Estimate	Std. error
# Children 0-2 years	-0.0637	0.0143	-0.0415	0.0175
# Children 3-6 years	-0.0391	0.0141	-0.0005	0.0163
# Children 7-9 years	-0.0006	0.0152	-0.0017	0.0167
# Children 10-14 years	0.0105	0.0152	0.0140	0.0162
# Children 15-17 years	-0.0032	0.0202	0.0250	0.0167
Unemployment rate previous year	-0.0015	0.0001	-0.0019	0.0001
Experience, years	0.0818	0.0335	0.1145	0.0171
Experience sq.	-0.0012	0.0002	-0.0003	0.0002
No change of occupation	0.0011	0.0155	0.0071	0.0142
Experience as researcher	-0.0016	0.0144	-0.0069	0.0167
Dummy: high tech	0.0029	0.0205	.	.
Dummy: 1996	-0.0650	0.2072	.	.
Dummy: 1997	-0.0602	0.1732	-0.0199	0.0276
Dummy: 1998	-0.0482	0.1385	-0.0920	0.0431
Dummy: 1999	-0.0620	0.1050	-0.0922	0.0624
Dummy: 2000	-0.0209	0.0713	-0.1482	0.0816
Dummy: 2001	-0.0167	0.0375	-0.2045	0.1023
Dummy: 2002	.	.	-0.2492	0.1228
Dummy: single	0.0634	0.0232	-0.0083	0.0246
Dummy: Trade	0.0093	0.0386	.	.
Dummy: Finance	-0.0340	0.0280	-0.1453	0.0866
Dummy: Personal services	-0.0081	0.0527	-0.1087	0.0835
Dummy: Capital	0.1927	0.1010	0.0460	0.0701
Dummy: 5 largest cities	0.0510	0.1086	0.0920	0.0686
Constant	12.0215	0.5832	11.2905	0.2312

Source: Own calculations using register data.

One interpretation of the results in Table 3.9 and Table 3.10 is that R&D occupations are attractive for individuals with a PhD background, and they are willing to accept a lower wage for working with R&D. This may be due to a higher degree of professional freedom and challenge in working with R&D, but it may also reflect a greater flexibility and less working hours in such occupations. Such aspects cannot be analyzed using the data available.

Similar analyses have been conducted for individuals with an ISCED 5A background, and the results are similar to those presented for PhDs. These can be obtained from the authors upon request.

Analyses have also been undertaken for the wage of PhD researchers subdivided by academic fields. The results from these exercises are also that there are generally no statistically significant wage changes associated with changing occupation from non-R&D to R&D occupations. This inability to find significant results for the PhDs probably reflect that the PhD population is small in Denmark. Results for researchers with ISCED 5A are similar.

Table 3.10 Determinants of researcher wage, PhDs, men, 1995-2002, fixed effects regression

	Private sector		Public sector	
	Estimate	Std. error	Estimate	Std. error
# Children 0-2 years	0.0026	0.0084	0.0010	.0072
# Children 3-6 years	0.0043	0.0084	0.0014	.0066
# Children 7-9 years	0.0263	0.0094	0.0105	.0066
# Children 10-14 years	0.0148	0.0094	0.0132	.0061
# Children 15-17 years	0.0343	0.0113	0.0238	.0066
Unemployment rate previous year	-0.0014	0.0001	-0.0015	.0001
Experience, years	0.2097	0.0230	0.0587	.0054
Experience sq.	-0.0014	0.0001	-0.0007	.0001
No change of occupation	0.0178	0.0086	-0.0030	.0056
Experience as researcher	-0.0111	0.0082	-0.0062	.0086
Dummy: high tech	0.0234	0.0159	.	.
Dummy: 1996	0.5864	0.1316	-0.0874	.0521
Dummy: 1997	0.4831	0.1100	-0.0823	.0446
Dummy: 1998	0.3827	0.0881	-0.0614	.0360
Dummy: 1999	0.3011	0.0663	-0.0428	.0271
Dummy: 2000	0.2147	0.0447	-0.0421	.0185
Dummy: 2001	0.1114	0.0238	-0.0157	.0100
Dummy: 2002	.	.	.	.
Dummy: single	0.0166	0.0149	-0.0003	.0112
Dummy: Primary sector	0.0752	0.0897	0.0558	.0998
Dummy: Energy	-0.0604	0.0566	-0.1761	.1223
Dummy: Construction	-0.1027	0.0940	.	.
Dummy: Trade	-0.1202	0.0251	-0.3289	.0781
Dummy: Finance	0.0342	0.0159	-0.1625	.0410
Dummy: Personal services	0.0184	0.0299	-0.1504	.0414
Dummy: Capital	-0.0717	0.0429	-0.0144	.0342
Dummy: 5 largest cities	-0.0531	0.0490	0.0157	.0341
Dummy: Social sciences	0.0563	0.1644	.	.
Dummy: Nature sciences	.	.	-0.0030	.0965
Constant	9.9510	0.4217	12.3772	.1147

Source: Own calculations using register data from Statistics Denmark.

3.8 The marginal return to R&D investment in Denmark

When considering the marginal return to R&D investment it is necessary to also consider the personnel resources available for R&D activities. TABLE 3.11 shows how the Danish potential researchers are currently distributed on scientific field and occupation. It appears that there is still some room for expanding R&D efforts, as there are free resources in almost all fields. This indicates that the wage regression results of Table 3.9 and Table 3.10 can be expected to hold for moderate expansions in the R&D effort in Denmark.

Table 3.11 PhDs by occupation and field, 2002

	Nature sciences	Social sciences	Technical sciences	Health sciences	Defense
Active researchers	701	1636	729	2609	1774
Total	820	2071	805	3389	1865

Source: Own calculations using register data from Statistics Denmark.

4. Conclusion – Part one

Research and development are gaining increased priority in economic policy around the world. For the EU countries the focus on R&D derives partly from a concern that competitive pressures from industries in developing countries will render whole ranges of European manufacturing industries economically unsustainable. Hence there is a perceived need to consider or identify the future industries of European countries. Besides, there is a growing understanding that R&D activities are an important part of fostering innovation, which can allow for the attainment of a persistent competitive advantage.

The understanding that R&D activities are an engine of growth goes back 50 years in the U.S., and a whole science has developed which seeks to understand the mechanisms of R&D and innovation. At a relatively early stage in the development of the science studies literature, it was agreed that innovation is not a linear process: simply giving money to R&D institutions does not necessary result in innovation. Innovation is the result of a complex interplay between firms, knowledge institutions, industry structure, the public sector etc.

In a European - but also in a Nordic – context, a relevant question is whether the prevailing structures can support dramatic increases in R&D activities. First of all: do the countries have an industrial base of firms which are oriented toward innovation, that is, will government-sponsored R&D activities find an end-user? Second: are the necessary “R&D factors of production” available?

This part of the report has considered the labour market for R&D personnel in Denmark. Mobility aspects of the R&D labour force have been considered, and the response of the wage of potential R&D personnel necessary to induce a change of occupation has been analyzed.

The results show no significant wage effect of changing occupation from a non-R&D occupation to an R&D occupation. This indicates that an increasing level of R&D activity does not lead to dramatic increases in the wage of R&D personnel – at least it did not for the labour market conditions prevailing in Denmark in 1995–2002.

Of course, the closer the economy comes to the capacity limit of R&D personnel, the less relevant will be the analyses of the wage of R&D personnel above. This calls for a close monitoring of the available resources for R&D.

Under the conditions of a continual availability of "free R&D personnel", existing literature indicate that the private rate of return to R&D is close to the return to other similar capital investment – around 11 per cent in Denmark. The social rate of return is commonly estimated to be much higher.

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5. Introduction – Part two

The performance of publicly financed research institutions has become a topic of major interest in many countries. The origins of this movement can be discussed. One theory is that globalization has led policy makers to believe in the need for further goal-orientation in public research and coordination between research and industry. Another theory is that a new tendency called “New Public Management” – an increasing focus on performance and accountability in the public sector – has put its mark on science policy as well as other areas of public policy and administration.

Publicly financed research institutions perform a number of important roles in society, and their performance is determined by the interplay between a wide range of factors and framework conditions. Hence, both the output and the input of public research institutions are many-dimensional in nature. Public research institutions do research and development, disseminate knowledge and often also undertake higher education. To do this, they employ scientific and other personnel, they use equipment, buildings etc., interact with other knowledge institutions, other public institutions and the private sector. They have a range of instruments to motivate personnel and students and operate within a given legal and budgetary framework.

Furthermore, the value of the output of public research institutions is difficult to measure – especially the output which relates to research. Research output may not find a use in the near future, and it may have effects on the functioning of society which are difficult to evaluate in economic terms.

It is therefore a difficult task to establish which factors are most important in determining the performance of public research institutions.

Several theories have been raised about the factors which determine public research institutions’ success, but few of the theories have been put to an empirical test, because there is a lack of data on the scientific outputs of the universities and the factors which determine the outputs. Existing theories point to the structure of research funding, the organization of research, internal diversity of universities and research networks as important factors in determining university output.

In this part of the report we put together a pilot database of the outputs and inputs of Nordic universities to test hypotheses of the relationship between universities’ publication activity, education output, unemployment rate of graduates, number of personnel and the structure of funding. The basis for the pilot database is a comprehensive paper on the design of a Nordic database on research institutions’ input and output, which was developed in the course of the project. The information in the pilot database is that which was in accessible from Nordic institutions and international databases and which could be collected with the resources of the project.

This part of the report thus has three contributions. First, it examines the potential for a Nordic database on research institutions' input and output. Second, it collects a useful pilot database. Third, it analyses tentatively the relationships between Nordic research institutions' input and output.

The following section describes the measurement of research input and output and gives a brief review of the literature on the determinants of the output of research institutions. Section 3 gives a brief overview of the research funding systems in the Nordic countries. Section 4 gives a thorough descriptive analysis of the relationship between the scientific output of Nordic universities, the personnel resources available, other types of output and the structure of research funding. This section also contains a brief discussion of the trade-off between economies of scale and knowledge dissemination at universities. Section 5 concludes.

6. The relationship between research institutions' input and output

6.1 Determinants of goal achievement

Some key determinants which have been established by the literature are, c.f. e.g. Stephan (1996), Lazear (1997) and Cherchye and Abeele (2005),

- the level of funding
- the structure of funding: base funding vs. competitive funding
- the input of personnel
- the composition of personnel: professors, associate professors, administrative staff etc.
- the quality of student input
- the level of managerial competence
- the possibility of performance related pay.

The level of funding affects the resources available for R&D, both in terms of physical capital or equipment, and in terms of the R&D personnel available. This also affects the R&D output quantity and quality. The structure of funding may also have an effect, as funding allocated on a competitive basis introduce an extra element of peer review and forces the individual researcher to consider carefully the project for which he or she applies for funding.

The input of personnel in terms of the total number of R&D personnel and the composition on professors, etc. naturally affects the quantity and quality of R&D.

The quality of the organization at R&D institutions may play an important role for the level of output of such institutions, c.f. e.g. Stephan (1996). The level of managerial competence in allocating personnel to different educational or R&D tasks may make a great difference to the quantity and quality of output. Also, the incentive structure formed by management of R&D institutions can be expected to affect the efforts of the personnel at R&D institutions and thereby also output.

6.2 Measuring scientific input and output

Science is generally thought to be something measurable and tangible where man is seen as unraveling the mysteries of the universe. To what extent can then different institutions/faculties be said to be involved in science or scientific research?

According to UNESCO, the definition of R&D is stated as: "Any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications[1]". In other words, R&D differentiates itself from knowledge by requiring an effort to devise new applications. Separate from science, but often related to it, are concepts such as invention and innovation, where the latter refer to new products that have a potential for generating commercial returns. A broad set of competencies and institutions become highly relevant in this context.

Furthermore, science originally referred essentially to the nature sciences, i.e., biology, physics and chemistry. Gradually, however, there has been a slide towards a broader connotation, with the term science applied within a range of faculties, probably as an instrument for gaining more credibility as science is associated with measurable hard facts. Previously, subjects such as the humanities had primarily been concerned with the creation and maintenance of knowledge. The scope of science has therefore been partly broadened, partly diluted, over time, a fact that we should recognize in the project and adapt to by applying measures which are in accordance with university methodology at each faculty.

Following the UNESCO definition, the output of R&D can be considered to be new knowledge and new applications, c.f. the discussion in Appendix B.

New knowledge takes many forms. Furthermore, different research units have different traditions for which form their output takes. The technical and nature sciences present their research output mainly in the form of articles in international peer-refereed journals. On the other hand the tradition among e.g. law departments is to publish mainly in national journals and in books.

This database borrows from the Norwegian experience on the development of a system of R&D evaluation and focuses on the following types of outlets: journal articles, monographs and contributions to anthologies. All the outlets considered must have either an ISBN or an ISSN-number, and they must have a tradition for peer review.

New applications can be measured using innovation surveys or patent data, c.f. Appendix B. It is outside the scope of this project to collect data

[1] UNESCO Statistical Yearbook, UNESCO, Paris, 68 and 65, Chap. 5. (latest update March 12, 2003).

on innovation, but the appendix specifies some possible sources for this kind of information.

The output of education is graduates at different levels. Thus, an indicator of the quantity of education output is the number of graduates at different levels of education. The disadvantage of this indicator is that different educations have different lengths and require different efforts to complete. Hence the same number of graduates from institutions in different countries may disguise important differences in the amount of education material that has been covered.

Another indicator of education output is the number of full time equivalents or “student years” produced in a year; this indicator summarizes the progress made by students at the research institutions. This indicator is robust to different educations having different length.

As an indicator of the quality of education, the unemployment rate of graduates measured one and two years after graduation is included.

Knowledge dissemination can take many forms, such as the direct collaboration with public and private organizations, the publishing of popular science literature, publishing of newspaper letters to the editor, giving speeches at non-academic conferences etc.

Presently the scope for including indicators of knowledge dissemination is limited, as most institutions have not developed systems for reporting dissemination performance, or the systems have only just been developed. At the time of writing, however, there is no consensus about how knowledge dissemination activities should be measured, so different R&D institutions report different indicators. At present it is therefore not possible to include an indicator of knowledge transfer from R&D institutions in the Nordic countries.

The scientific input used to produce new knowledge and education is primarily researcher time, which is measured for different categories of personnel such as full professors, assistant professors and PhD students. These indicators of R&D input are supplemented by information on the structure of R&D funding, divided into external and base funding. Finally, an indicator of management structure is included, as there is an indicator of whether university management is hired or elected.

7. Comparing public funding of R&D in the Nordic countries

The public funding of R&D in the Nordic countries is on certain stretches very similar and on others very different. One of the similarities is the level of public R&D expenditure. The lowest level is found in Denmark and Norway at approximately 0.8 per cent of GDP, while Iceland has the highest level of public funding at approximately 1.2 per cent of GDP. The total level of R&D expenditure, on the other hand, varies considerably across the Nordic countries, cf. Figure 7.2.

Another similarity is that the level of public R&D expenditure is above EU-average in all Nordic countries. Moreover, a comparison across OECD-countries shows a positive relationship between public and private R&D expenditure. It is therefore not surprising that the Nordic countries are among those with the highest level of business R&D expenditure as well as, cf. Figure 7.3.[2]

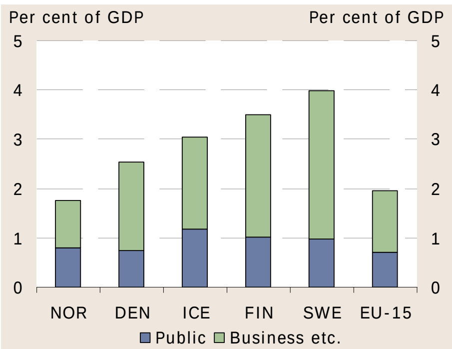

Figure 7.2 R&D expenditures in the Nordic countries, 2003

Note: "Public" refers to government budget appropriations. "Business etc." is estimated as the difference between Gross Domestic Expendi-ture on R&D and public expenditures and covers both business R&D ex-penditures as well as other sources of funding. Favorable tax treatment of enterprises carrying out R&D is not included in the numbers. The Norwegian arrangement has a sub-stantial size: 1.2 billion NOK.
Source: OECD (Main Science and Technology Indicators), 2006

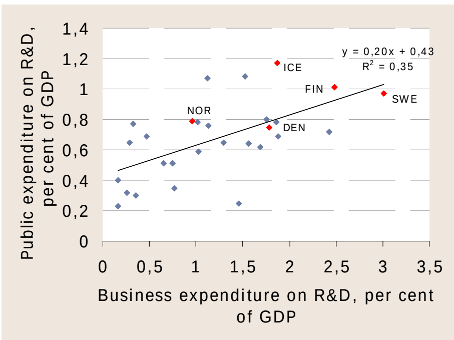

Figure 7.3 R&D expenditures in the OECD countries, 2003

Note: The t-value with respect to the slope is 3.47. Hence, the relationship is statistical significant at 1 per cent level.
Source: OECD (Main Science and Technology Indicators), 2006

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[2] While it cannot be rejected that the level of public R&D expenditures might affect the level of business R&D expenditure to a certain extent, it is important to be careful with the interpretation of the relationship. The different level of R&D expenditures across countries is more likely determined by the different structure of trade and industry, for instance the share of high-tech industries; see Nordic Council of Ministers (2005).

The comparison in the rest of this section is delimited to R&D appropriations within the federal government budget. The conclusions, however, are expected to hold for the total public R&D expenditures as the lion's share of public R&D expenditure is defrayed through the federal government budget in all Nordic countries.

Internal versus external funding

When describing the structure of public funding of R&D it is common to distinguish between internal and external funding.[3]

Box 7.6 research councils administrating external funds

It is a common feature across the Nordic countries that a substantial part of external funding is allocated through research councils or government institutions. The organization of councils, however, is different. Norway and Iceland has one coordinating council/government institution. Moreover, the Norwegian council is not only responsible for the allocation of external funding but also internal funding. Denmark and Finland have two councils/institutions. In Denmark The Independent Research Council supports research based on the scientists' own ideas, while the Strategic Research Council supports research within areas of political prioritization and enhance the interplay between public and private research. In Finland, the distinction between the two institutions is different. The Academy of Finland supports basic and applied research, while TEKES supports innovation projects both within public and private research. Sweden, in contrast to the other Nordic countries, has several research councils. The two most important ones – in terms of funds – are the Scientific Council (SC) and VINNOVA. SC supports basic research in all academic disciplines, while VINNOVA supports innovation linked to research and development.

	Research councils/Government agencies	Number of sub-councils
Denmark	The Independent Research Council	5
	The Strategic Research Council	5
Finland	Academy of Finland	4
	TEKES	-
Iceland	RANNIS	-
Norway	Research Council of Norway	6
Sweden	The Scientific Council	5
	VINNOVA	-
	FAS	-
	FORMAS	-

Internal funding refers to basic appropriations granted to universities and public research institutions (PRI). Basic appropriations are mostly

[3] Internal funding is sometimes referred to as institutional funding, while external funding is referred to as project funding.

granted unconditionally on future activities, giving the institutions a large degree of freedom to prioritize among different research areas.[4] It is, however, common practice across the Nordic countries that universities and PRI's enter into a performance agreement with the responsible government authority, as the government ultimately carries the political responsibility. These agreements usually incorporate a broad number of performance indicators, such as the number of students enrolled, graduates, scientific publications, international cooperation etc. While the allocation of internal funding is not directly attached to these agreements, they do serve the purpose of enhancing focus on measurable results.

External funding, on other hand, refers to funding that is subject to open competition among potential applicants. External funding is often allocated on a project-by-project basis. It is common practice that the incoming applications for project funding undergo a peer review conducted by a board of experts, with academic researchers making up the majority in most cases. This process is usually carried out by research councils or government institutions. The organization of research councils in the Nordic countries are briefly described in box 7.1.

Comparing the importance of internal versus external funding shows a somewhat different structure across the Nordic countries. In Finland, more than 50 per cent of public R&D expenditures are externally funded while it is less than 20 per cent in Sweden, cf. Figure 7.4.[5] The structure of funding also differs with respect to whether the funding is granted to general scientific research or to predefined research areas (strategic research). In Finland, the majority of public funding is directed to a predefined area. In Denmark, on the other hand, the majority is directed to general scientific research, cf. Figure 7.5.

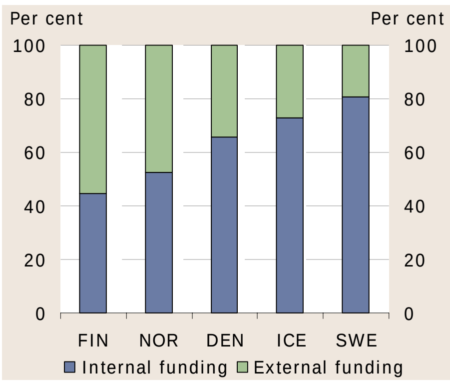


Figure 7.4 Division of Government R&D appropria-tions into internal and external fund-

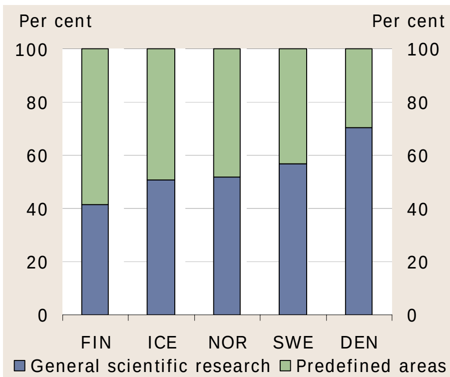


Figure 7.5 Division of government R&D appropria-tions into general scientific researchs

[4] Public research institutions, however, is usual operating within a certain area, for instance agriculture, which provides a natural boundary for the relevant areas of research.

[5] However, 20 per cent of public R&D expenditures in Sweden are directed to defense. If these expenditures are left out in the calculation, external funding makes up approximately 25 per cent of public R&D expenditures.

ing, 2005.

Source: Nordic Council of Ministers (2005) and own calculations.

and predefined areas, 2005.

Source: Nordic Council of Ministers (2005) and own calculations.

When it comes to internal funding, however, the majority is directed to general scientific research in all Nordic countries, cf. Figure 7.6. The largest share is found in Denmark, where 80 per cent of internal funding is directed to general scientific research, while the lowest share at 50 per cent is found in Iceland. This is not surprising at all, as universities generally receive the largest share of internal funding and usually have a large degree of freedom when it comes to decide the use of these funds.

External funding, on the other hand, is to a larger extent directed to predefined research areas. This is especially the case in Finland and Norway, where more than 70 per cent of external funding is directed to predefined research areas, cf. Figure 7.7.

The use of external funding has in recent years received growing political attention, as more competition – also in the area of public R&D funding – presumably carries some gains of efficiency. While the theoretical arguments in favor of external funding might seem convincing, the empirical evidence supporting this view is scarce, cf. Cherchye and Abeele (2005).

Today, it is an explicit policy goal in Denmark and Iceland to increase the share of external funding, cf. The Danish Government (2006) and The Science and Technology Council (2004). In Denmark and Norway, the degree of external funding also enters as an indicator in the performance agreements between universities and governments. While it is evident that the ability to raise funds is important, a direct link between external funding and the quality of research cannot be taken for granted. However, the promotion of external funding might improve the co-operation between different research environments and public and private research.

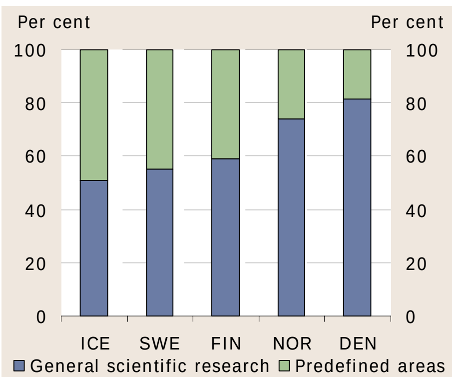


Figure 7.6 Division of internal into general scientific research and predefined research areas, 2005

Source: Nordic Council of Ministers (2005) and own calculations.

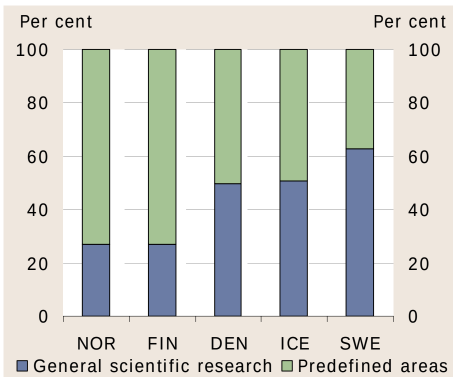


Figure 7.7 Division of external funding into general scientific research and predefined research areas, 2005

Source: Nordic Council of Ministers (2005) and own calculations.

Co-ordination of public R&D policy

Within the last couple of decades it has become evident that fostering new and gainful insights from scientific research is an interdisciplinary task, cf. Nordic Council of Ministers (2005). Thus, there is a widespread political interest in designing governance and public funding systems that promotes integration and coherence all the way from basic research to commercial success.

Comparing the organization of public R&D funding at the ministry level is one indicator of this thinking. A common feature across the Nordic countries is that only a few ministries are responsible for the bulk of public funding of R&D, though public research institutes generally belong under the relevant ministry.

The ministries responsible for education and industry are usually the two ministries involved in the bulk of public R&D funding, with education having the largest share, see Table 7.2. Denmark, however, have collected the bulk of public R&D funding in one ministry: Ministry of Science, Technology and Innovation. And R&D expenditures make up the majority of the ministry’s budget as opposed to the other Nordic countries.

Collecting the political responsibility of public R&D funding under “one roof” is believed to reduce the need for horizontal coordination, hence easing the interdisciplinary task. It could also be argued that the prioritization of public R&D expenditures is strengthened, as public R&D expenditures become more transparent. However, the opposite view has also been put forward, as public R&D expenditures more clearly combat with other fields of policy, see Technopolis (2003). Moreover, coordination within one institution is not necessarily more effective than coordination across institutions. And collecting the responsibility in one Ministry might lead to loss of sector knowledge as well as focus on research in distinct areas.

Table 7.2 The three ministries with the largest share of public R&D appropriations, 2005-budget

	Percent of total state budget to R&D	Percent of Ministry's budget
Denmark		
Ministry of Science, Technology and Innovation	76.4	55.0
Ministry of Food, Agriculture and Fishery	5.2	28.8
Ministry of Culture	4.7	10.3
Finland		
Ministry of Education	42.1	10.8
Ministry of Trade and Industry	34.3	55.9
Ministry of Social Affairs and Health	7.3	1.2
Iceland		
Ministry of Education, Science and Culture	58.2	38.4
Ministry of Fisheries	15.0	59.3
Ministry of Health and Social Security	7.6	2.4
Norway		
Ministry of Education and Research	53.2	22.5
Ministry of Trade and Industry	8.7	32.9
Ministry of Health and Care Services	7.0	1.3
Sweden		
Ministry of Education, Research and Culture	52.3	n.a.
Ministry of Defense	20.5	n.a.
Ministry of Industry and Trade	12.8	n.a.

Note: It should be noted that the name of ministries might have changed due to reorganization.
Source: Nordic Council of ministers (2005).

As opposed to the Danish model, the coordination of R&D policy in the other Nordic countries – except from Sweden - is pursued through a political council, see Technopolis (2003). Finland and Iceland have a single political council, which is responsible for coordination and chaired by the prime minister. In Norway, the coordination of R&D policy is placed under the Government Research Committee, while the Research Council of Norway is giving advice to the government on R&D issues. This council also carries the full responsibility of the allocation of public R&D funding, providing an excellent opportunity of coordination. In Sweden, the responsibility of policy coordination on R&D issues has been placed under the minister of education and research.

8. Analysis of universities' input and output

8.1 Pilot database on activity indicators in the Nordic university sector

An important part of this report has been the collection of data concerning the activity at universities in the Nordic countries, including Denmark, Finland, Norway and Sweden[6]. The data has been collected for the period 1997–2005 and is reprinted in part in Appendix A. An overview of the variables included in the pilot database is given in Table 8.3.

This section gives an overview of what sort of information that can be drawn for the database. However, it has not been the intention to attempt to uncover all relevant findings. There is certainly scope for further investigation into the similarities and differences.

It is, however, important to stress that it is a pilot database and that a great deal of limitations applies. Hence, the present database is not suitable to draw any firm conclusions, but a tool to be further developed and hopefully a tool from which interesting questions for further exploration will emerge.

First of all, the establishment of the database is partly based on national sources. Though a good deal of effort has been devoted to ensure the comparability of the limited numbers of indicators, the national sources might be built on different principles.

Secondly, the database has to be extended with more detailed indicators to uncover the differences and similarities within the university sector in the Nordic countries. For instance, further investigation of productivity levels should be based on a closer link between input and output measures. This involves, as a minimum, a division of personnel into the time spent on researching and teaching, respectively.

[6] Centre for Economic and Business Research (CEBR) at Copenhagen Business School has coordinated the collection of data. However, the database had never been a reality without invaluable help from different Nordic institutions. These include NIFU STEP (Norway), IKED (Sweden), University of Tampere (Finland) and Dansk Center for Forskningsanalyse (Denmark).

Table 8.3 Variables in the pilot database

Variables	Remarks
Staff	The number of staff includes scientific, teaching, technical and administrative personnel. Staff is measured in full time equivalents (fte). These data have been collected through national sources.
Publications	Publications include articles, reviews and letters published in international peer reviewed journals. Books and anthologies are not included. Web of Science has been used as common source.
Graduates	The number of graduates includes bachelors, masters, Ph.D.'s and other degrees taken at universities. However, degrees which cater for people working are generally not included. These data have been collected through national sources.
External funding	The share of total funding coming from other sources than governments basic appropriations. These data have been collected through national sources.
Unemployment	The unemployment rate among graduates. Labor market status is on average registered approximately 6-12 months after graduation. However, the method of calculation differs between the countries.

Thirdly – and along the same line of reasoning – it is important to bear in mind that the indicators are only quantitative measures. Controlling for different kinds of qualitative aspects, such as examination marks, the number of citations to scientific publications, ranking of scientific personnel etc. will most likely improve the accurateness and comparability of the indicators.

Despite the obvious limitations, the database is a starting point to give a first insight when it comes to comparing input, output and productivity across the universities in the Nordic countries and a stepping stone for further exploration of this area.

8.2 Staff in the university sector

The number of persons – measured in full time equivalents – employed in the university sector in the Nordic countries was approximately 17,000 in Norway, 20,000 in Denmark, 30,000 in Finland and 45,000 in Sweden in 2005, cf. Figure 8.8. The staff in the university sector has generally increased in all Nordic countries in the period considered. The largest increase – in percentage terms – has occurred in Denmark and Norway, where the staff in the university sector increased rather more than 25 per cent from 1997 to 2005 in both countries, cf. Figure 8.9.

When it comes to the share of the population working in the university sector, then Finland takes the leading position. In Finland there is close to 6 persons employed in university sector for every 1,000 inhabitants. In Sweden 5 persons for every 1,000 inhabitants is employed in the university sector, while it is close to 4 persons in Denmark and Norway, cf. Figure 8.10. The share of the population working in the university sector has generally increased over the period 1997–2005. The largest increase of 25 per cent has occurred in Denmark, cf. Figure 8.11.

8.3 Publications

From an overall perspective, *scientific work* and *education* are the two main tasks carried out in the university sector.

The results from scientific work are usually presented in scientific publications. Hence, the number of scientific publications is one possible measure of output from this work.

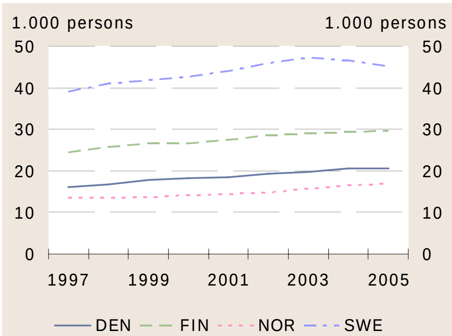


Figure 8.8 Number of staff (FTE), 1997-2005

Source: Pilot database on activity indicators at Nordic universities.

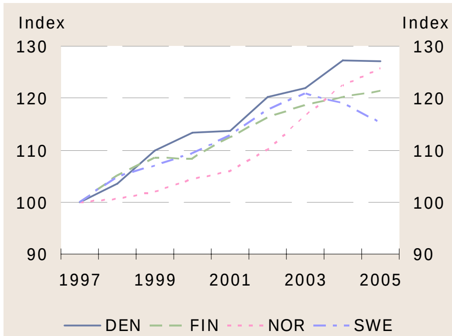


Figure 8.9 Development in total staff (fte), 1997=100.

Source: Pilot database on activity indicators at Nordic universities.

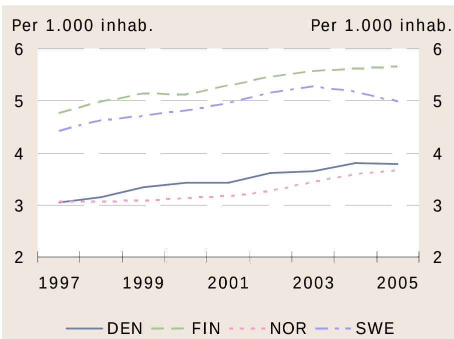


Figure 8.10 Staff (fte) per 1.000 inhabitants, 1997-2005

Source: Pilot database on activity indicators at Nordic universities.

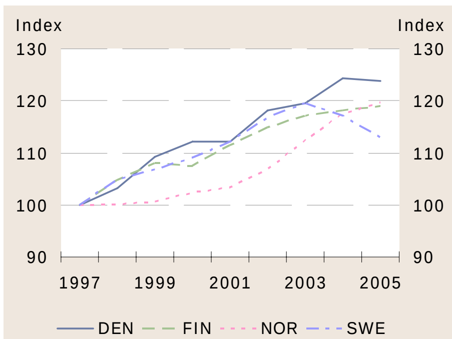


Figure 8.11 Staff (fte) per 1.000 inhabitants, 1997=100

Source: Pilot database on activity indicators at Nordic universities.

The number of scientific publications in 2005 – excluding books and anthologies – was approx. 5,000 in Norway, 6.000 in Denmark, 8,000 in Finland and 18,000 in Sweden, cf. Figure 8.12. The number of publications has generally increased in all Nordic countries in the period considered, cf. Figure 8.13. The largest relative increase has occurred in Norway, where the number of publications increased with 50 per cent in 1997–2005. Half of this increase happened from 2004 to 2005.

It is important to notice that the number of publications does not include books and anthologies. Books and anthologies make up more than half of the total number of scientific publications in Finland, cf. box 8.1. Moreover, the importance of books and anthologies varies considerably across universities in Finland. It is thus important to be aware of the fact that the ranking of universities based on the number of scientific publications or scientific publications per staff might be altered significantly if books and anthologies were included.

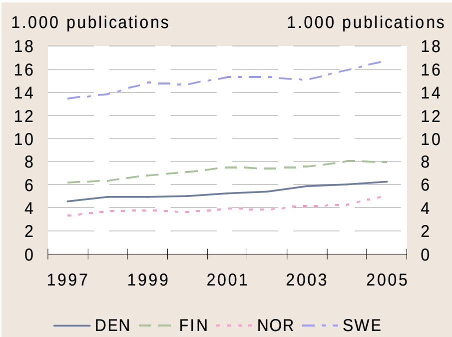


Figure 8.12 Number of publications, 1997-2005

Note: Publications do not include books and anthologies.
Source: Pilot database on activity indicators at Nordic universities.

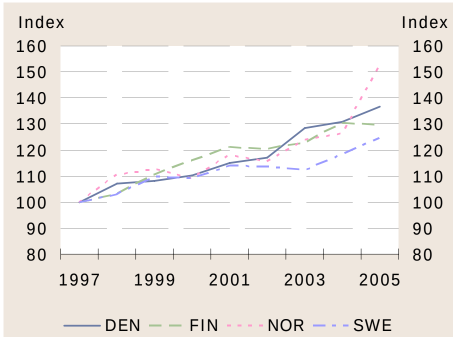


Figure 8.13 Number of publications, index 1997=100

Note: Publications do not include books and anthologies.
Source: Pilot database on activity indicators at Nordic universities.

Box 8.7 The importance of books and anthologies in the university sector in Finland

Scientific books and anthologies make up more than half of the scientific publications in Finland. The number of scientific books and anthologies was close to 12.000 in 2005, while the number of articles was approximately 8.000, cf. Figure 8.14. The number of scientific publications has generally increased over the period considered, while the relationship between articles on one hand and books and anthologies on the other hand has been fairly stable. However, the importance of books and anthologies varies considerably across universities, cf. Figure 8.15.

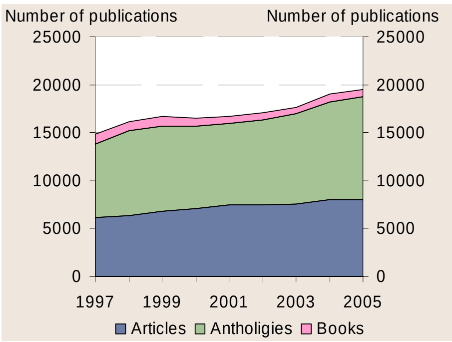


Figure 8.14 Scientific articles, anthologies and books, 1997-2005

Source: Web of Science and Kota-database (http://kotaplus.csc.fi:7777/online/Etusivu.do).

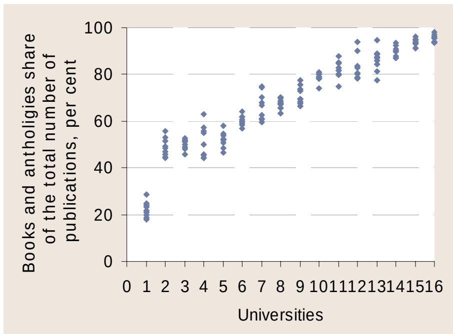


Figure 8.15 Books and Anthologies share of the total number of publications

Source: Web of Science and Kota-database (http://kotaplus.csc.fi:7777/online/Etusivu.do).

8.4. Graduates

Education is the second main task carried out in the university sector. An obvious measure of the output associated with education is, of course, the number of graduates. Not surprisingly, the number of graduates is largest in Sweden with 50.000 in 2005, cf. Figure 8.16. The number of graduates has generally increased in recent years in the Nordic countries. This has especially been the case in Norway, Sweden and Denmark, cf. Figure 8.17.

While the increase in the number of graduates to some extent reflects a rise in take-up rates in recent years, it is also important to be aware of the fact that different reforms of the educational system have had an impact on the number of graduates and the activity in the university sector in general. The bachelor degree, for instance, was first introduced in the Norwegian university sector in 2003.

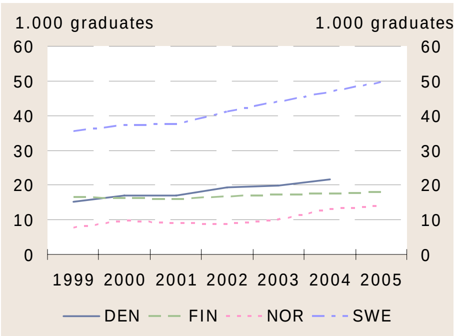


Figure 8.16 Number of graduates, 1999-2005

Note: The number of graduates in Norway excludes graduates from University of Stavanger due to missing values before 2001. The number of graduates from University of Stavanger in 2005 was approximately 2.300 or 14 per cent of the total number of graduates this year. Moreover, the number of graduates in Norway is generally underestimated because some bachelor degrees are integrated in master degrees.
Source: Pilot database on activity indicators at Nordic universities.

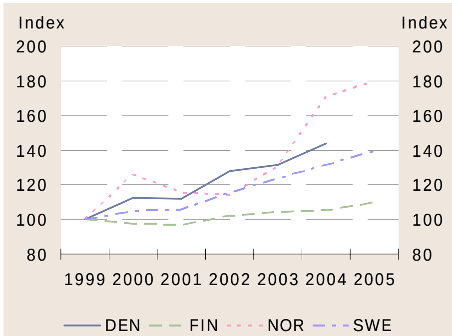


Figure 8.17 Development in number of graduates, 1999=100

Source: Pilot database on activity indicators at Nordic universities.

8.5 The degree of concentration of activity

With the database it is possible to shed some light on the concentration of activity in the university sector in the Nordic countries. One way to measure concentration is to look at the activity carried out by the largest universities compared to universities' total activity.

Using this method shows that the concentration of activity is highest in Norway and lowest in Sweden, cf. FIGURE 8.18 and FIGURE 8.19. Sweden differs from the other three Nordic countries, when looking at the university with the largest share of total activity, cf. FIGURE 8.18. This may be due to the fact that several larger cities exist in Sweden.

The ranking of countries is almost the same whether the activity is measured by graduates, staff or publications. The magnitude of concentration, however, depends on the indicator of activity. The activity is generally more concentrated when using the number of publications as an indicator compared to using staff or graduates. And using graduates gives the lowest degree of concentration. This finding is common across the Nordic countries.

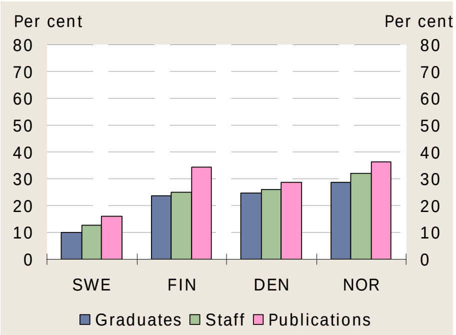


Figure 8.18 The largest university's share of total graduates, staff (fte) and publications

Source: Pilot database on activity indicators at Nordic universities.

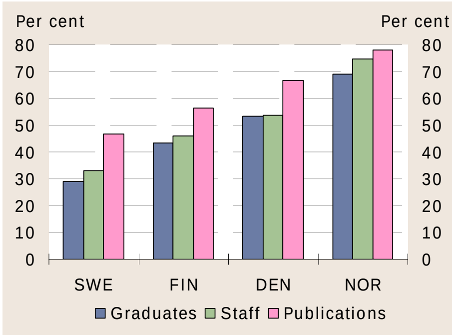


Figure 8.19 the three largest universities' share of total graduates, staff (fte) and publications

Source: Pilot database on activity indicators at Nordic universities.

8.6 Productivity

With the database it is also possible to give a rather rough picture of the productivity levels at Nordic universities. The two measures that can be deduced from the database are: *scientific publications per staff* and *graduates per staff*. These measures are, however, nowhere near perfect, as discussed in the introduction and later in this section. Hence, it is very important to stress that the following findings should be treated with due caution.

The number of scientific publications per staff is generally higher in Sweden than in the three other Nordic countries, cf. Figure 8.20. In all four countries there has been a slight increase in the number of publications per staff during the period 1997 to 2005, cf. Figure 8.21.

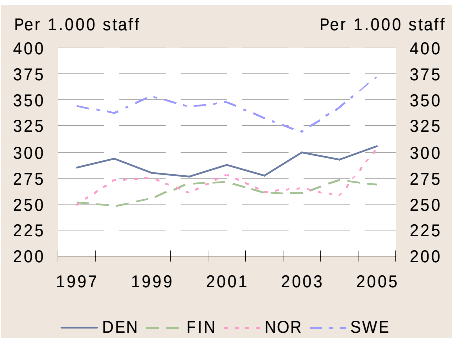


Figure 8.20 Publications per 1.000 staff (fte), 1997-2005

Source: Pilot database on activity indicators at Nordic universities.

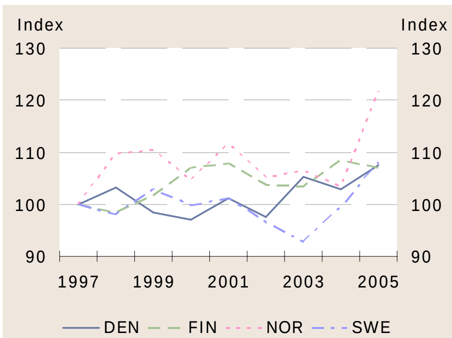


Figure 8.21 publications per staff (fte), index 1997=100

Source: Pilot database on activity indicators at Nordic universities.

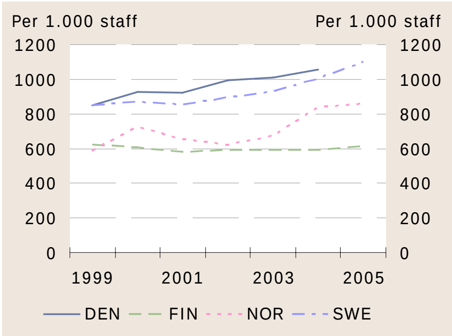


Figure 8.22 Graduates per 1.000 staff (fte), 1999-2005

Note: It is important to notice that the level of graduates per staff is understated in Norway because University of Stavanger is excluded. See also the note to figure 1.7. The number of graduates per 1.000 staff in 2005 rises to 957 if University of Stavanger is included.
Source: Pilot database on activity indicators at Nordic universities.

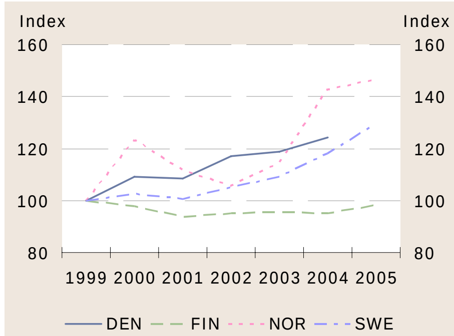


Figure 8.23 Development in graduates per 1.000 staff (fte), 1999=100

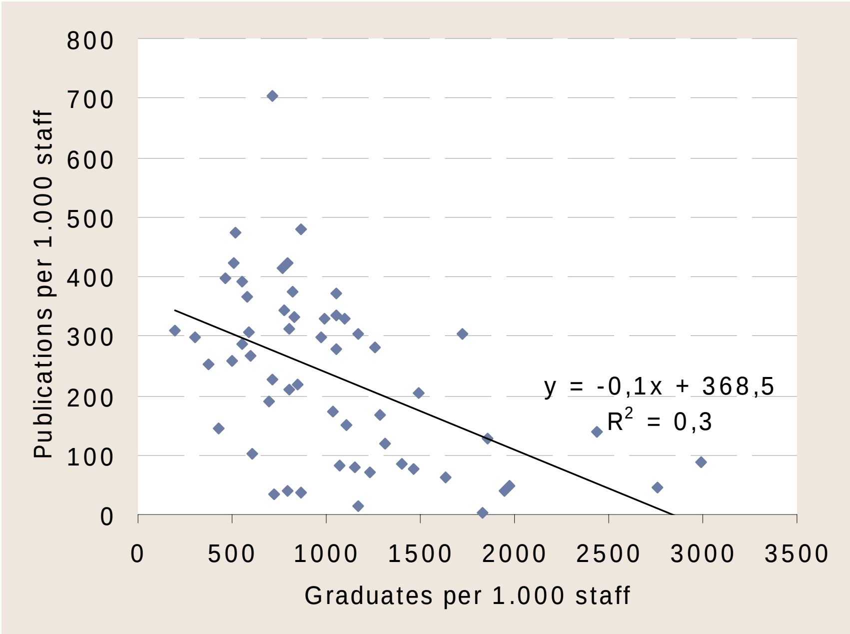
Source: Pilot database on activity indicators at Nordic universities.

The picture is somewhat different when looking at graduates per staff. The number of graduates per staff is significantly lower in Finland than in the three other Nordic countries, cf. Figure 8.22. Moreover, there has been a considerable increase in the number of graduates per staff in Denmark, Norway and Sweden, while this relationship has been more or less constant in Finland in the last five years, cf. Figure 8.21.

With two different measures of productivity, it is obvious to investigate the relationship between the two. A comparison across the Nordic universities clearly shows a negative correlation between publications per staff and graduates per staff, cf. Figure 8.24. This relationship suggests that specialization – either in scientific work or in education – is taking place to some degree.

Another possibility is to look at the relationship between productivity and the size of universities. Comparing the number of scientific publications per staff with the number of staff shows a positive correlation, cf. Figure 8.25. The number of graduates per staff is, on the other hand, negatively correlated with the size of university, cf. Figure 8.26.

Figure 8.24 Graduates per staff (fte) versus publications per staff (fte)



Note: For each university the productivity measures are the average of the last three years' productivity. The t-value with respect to the slope is 4.39. Hence, the relationship is statistical significant at 1 per cent level.
Source: Pilot database on activity indicators at Nordic universities.

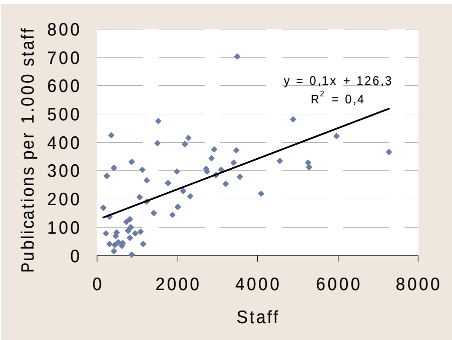


Figure 8.25 Publications per staff (fte) and number of staff (fte)

Note: The t-value with respect to the slope is 5.56. Hence, the relationship is statistical significant at 1 per cent level.

Source: Pilot database on activity indicators at Nordic universities.

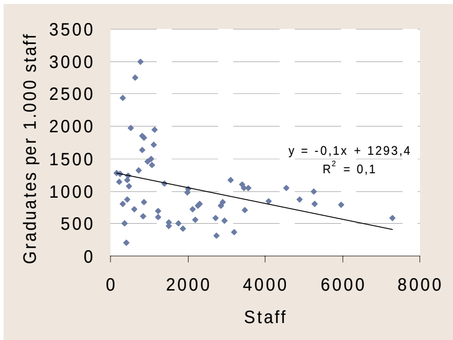


Figure 8.26 Graduates per staff (fte) and number of staff (fte)

Note: The t-value with respect to the slope is 2.72. Hence, the relationship is statistical significant at 5 per cent level.

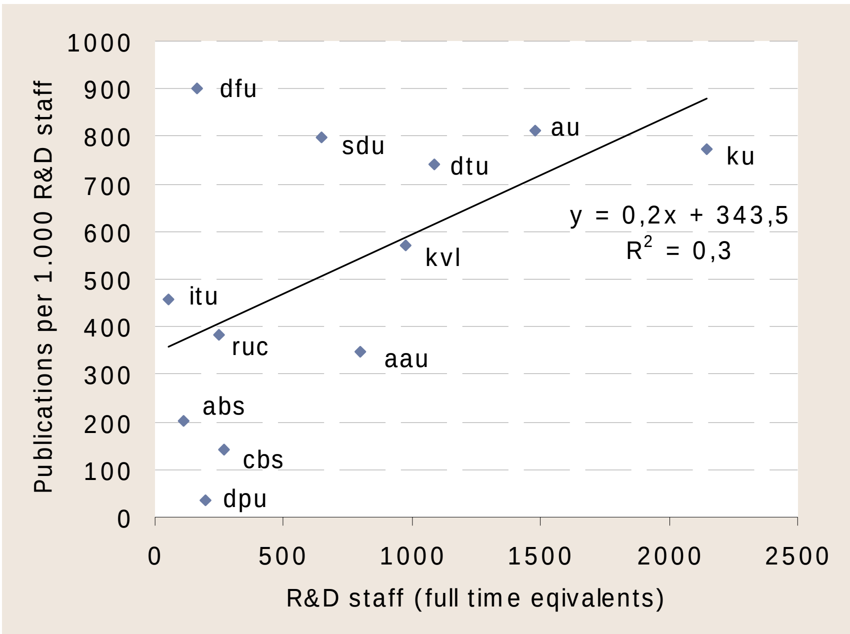
Source: Pilot database on activity indicators at Nordic universities.

It is, however, impossible to draw any safe conclusions from these simple relationships. First of all, they only show a partial picture. Including more explanatory variables might alter the picture considerably, see next section. Second, some kind of lag structure in the relationships is not captured in these descriptive analyses. Third, as earlier mentioned, books and anthologies are not included in the number of publications. Finally, the relationships may be the result of specialization in the sense that large universities specialize in scientific work while small universities specializes in education.

A comparison across Danish universities, however, indicates that there might be economies of scale when specialization is controlled for, cf. figure 8.20. The figure thus shows a positive correlation between the number of scientific publications per R&D personnel and the size of R&D personnel. [7]

However, this finding should also be treated with caution, as the number of scientific publications from a given university most likely depends on the composition of research areas due to different traditions of publication. How to acknowledge co-authors or minor contributors, when scientific work is published, is one aspect where traditions differ widely across research areas. Other aspects could be the general requirements to a scientific publication, the degree of complexity or simply the average length of scientific publications in different research areas. Hence, it seems more reasonable to compare productivity within the same area of research. A similar argument could be raised when it comes to comparing the number of graduates per staff or teaching staff. In this case it seems more reasonable to compare the productivity for different types of degrees, e.g. bachelors, masters and Ph.D.'s.

Figure 8.27 Publications per R&D personnel (fte) and the number of R&D personnel (fte) at danish universities.



Note: The t-value with respect to the slope is 2.08. Hence, the relationship is statistical significant at 5 per cent level. ku: Copenhagen University, au: Aarhus University, sdu: University of Southern Denmark, dtu: Technical University of Denmark, cbs: Copenhagen Business School, ruc: Roskilde University, abs: Aarhus Business School, aau: Aalborg University, kvl: Royal Agricultural and Veterinary University, dfu: Danish Pharmaceutical University, dpu: Danish University of Education, itu: IT-University. '

Source: Pilot database on activity indicators at Nordic universities and Dansk Center for Forskningsanalyse.

[7] It is important to notice that the size of R&D personnel is not the number of scientific personnel but the time spent on R&D by university staff.

8.7 External funding

Government basic appropriations generally play an important role in financing the activity in the university sector. However, a very large share of funding is external. External funding usually refers to funding – both public and private – that is subject to competition among potential applicants. Some private funding of universities, though, is also granted unconditionally. This is often the case with funding from private non-profiting organizations, for instance organizations with a charitable purpose.

The degree of external funding is highest in Sweden at 50 per cent and lowest in Denmark at 30 per cent, cf. Figure 8.28. It is important to notice that the degree of external funding presented in this section cannot be compared to the one presented in section 7 due to different approaches. The degree of external funding seems to increase with the size of universities. However, there is a considerable variation in the degree of external funding for universities with less than 1.000 employed, cf. Figure 8.29.

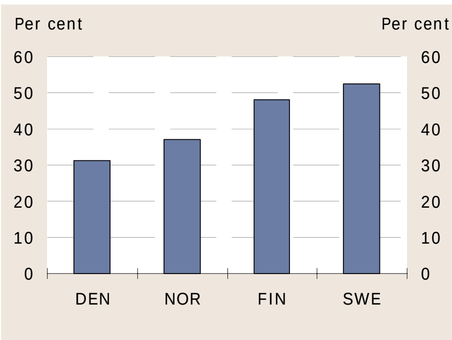


Figure 8.28 Average Degree of external funding, per cent

Note: The average degree of external funding for each country is calculated by weighing the degree of external funding for each university with the number of staff. The degree of external funding for each univer-sity is the average over the last three years. The degree of external funding in Norway is 2003-data.
Source: Pilot database on activity indicators at Nordic universities.

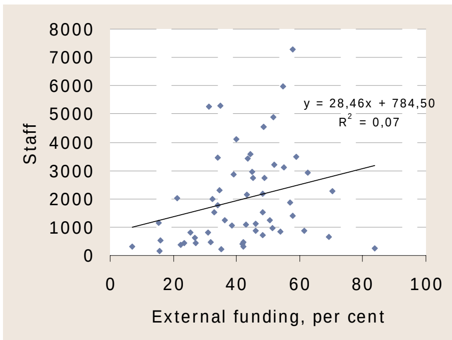


Figure 8.29 Degree of external funding and number of staff (fte)

Note: The t-value with respect to the slope is 1.96. Hence, the relationship is statistical significant at 5 per cent level. The degree of external funding is the average for each university over the last three years.
Source: Pilot database on activity indicators at Nordic universities.

From a partial point of view there is a positive correlation between the number of publications per staff and the degree of external funding, cf. Figure 8.30. The number of graduates per staff is, on the other hand, decreasing with the degree of external funding, cf. Figure 8.31. However, these relationships might just reflect that large universities have a higher degree of external funding and that a relative large share of their staff is carrying out scientific work and vice versa with small universities. Hence, no safe conclusions can be drawn from these simple relationships.

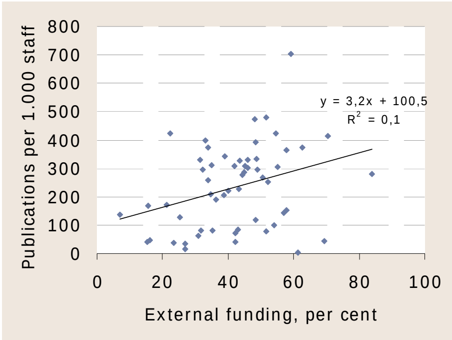


Figure 8.30 publications per staff and external funding

Note: The t-value with respect to the slope is 2.50. Hence, the relationship is statistical significant at 5 per cent level.

Source: Pilot database on activity indicators at Nordic universities

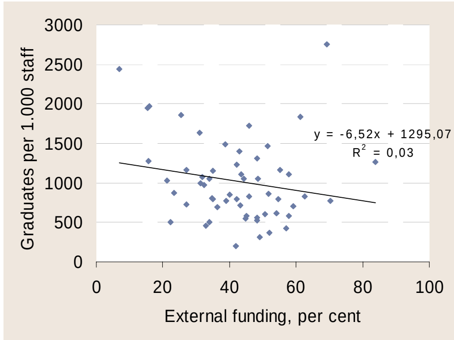


Figure 8.31 Graduates per staff and external funding

Note: The t-value with respect to the slope is 1.39. However, if the outlier in the northeast corner of the chart is removed, the t-value rises to 2.67 and R^2 to 0.12.
Source: Pilot database on activity indicators at Nordic universities.

8.8 Unemployment among graduates

One way of qualifying the comparison of performance across universities is to look at labor market performance for graduates.
The unemployment rate after graduation is generally lowest in Finland and Sweden and highest in Denmark and Norway, cf. Figure 8.32. While this picture could reflect differences in the quality of educations, it is more likely this finding is mainly explained by institutional settings, for instance the design of public benefit systems and the composition of educations. Moreover, it is worth noticing that the differences are not explained by the overall unemployment rate.

It is widely recognized that education generally improves labor market prospects. However, the chance of finding a job also depends on several other factors, including the specific education or maybe even the university from which one has graduated. A comparison of the unemployment level among graduates from the different Nordic universities shows a considerable variation, supporting the latter view. The variation in unemployment rates, however, cannot be explained by the size of universities, cf. Figure 8.33.

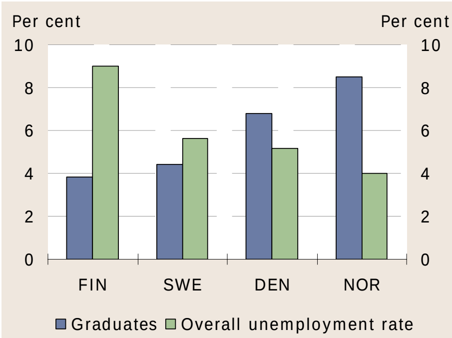


Figure 8.32 Unemployment rate after graduation

Note: Labor market status is on average registered approximately 6-12 months after graduation. However, the method of calculation differs between the countries. The average unemployment rate at country level is calculated by weighing the unemployment rate for each university with the number of graduates. The unemployment rate for graduates at each university is the average for the period 2001-2003.
Source: Pilot database on activity indicators at Nordic universities and OECD, Employment Outlook 2006.

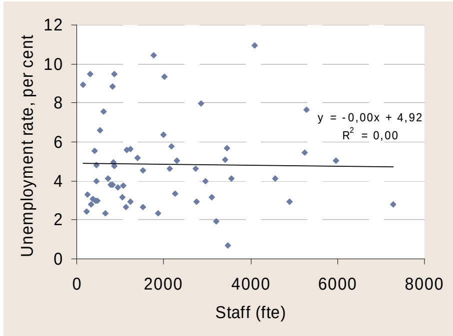


Figure 8.33 Unemployment rate for graduates and number of staff (FTE)

Note: The t-value with respect to the slope is 0.13. Hence, the relationship is statistical insignificant at 5 per cent level.
Source: Pilot database on activity indicators at Nordic universities.

Likewise, there seems to be no connection between the level of productivity and the unemployment rate after graduation. This holds for both measures of productivity, cf. Figure 8.34 and Figure 8.35.

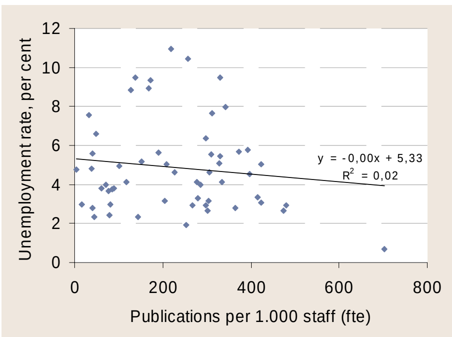


Figure 8.34 publications per staff (fte) and unemployment rate after graduation

Note: The t-value with respect to the slope is 0.93. Hence, the relationship is statistical insignificant at 5 per cent level.
Source: Pilot database on activity indicators at Nordic universities.

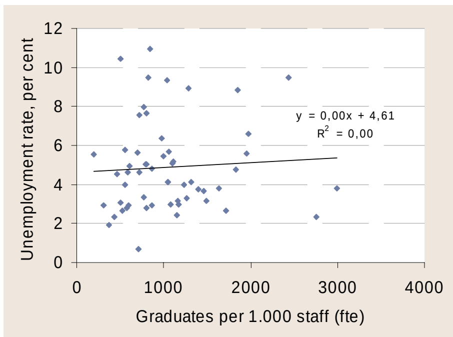


Figure 8.35 Graduates per staff (fte) and unemployment rate after graduation

Note: The t-value with respect to the slope is 0.45. Hence, the relationship is statistical insignificant at 5 per cent level.
Source: Pilot database on activity indicators at Nordic universities.

8.9 Multivariate analyses of the relation-ship between university input and output

The bivariate relationships between universities' publications, graduates etc. found in the previous section give an important idea of how the universities trade off different outputs against each other, and how size enters in determining the quantity of university output. On the basis of the analysis of the previous section, we go on to examine the relationship between the input and outputs in a multivariate framework where the influence of a larger number of factors is controlled for.

The analysis of this section is very preliminary and represents a first effort on the newly collected pilot database. The results in the following should not be interpreted as established causal relationships, but rather as a more sophisticated form of description of the data than the one presented in the previous subsection. All the analysis performed is reduced form, which once again underscores that the parameter estimates found should only be interpreted as correlations rather than causal relationships. The analysis is, however, valuable because it does give an idea of how different university inputs and outputs interact while controlling for a range of factors which could potentially cloud the impression obtained from simple correlations. If, for example, the form of the relationship between publications and staff is concave, it is evidence against the widely held belief that there are scientific advantages from scale. Furthermore, if there is a statistically significant relationship between the degree of external funding and research output, it provides inspiration for further analysis of which is the right causal relationship.

A final caveat: The pilot database is incomplete in the sense that a wide range of input and output indicators are missing. This is both due to fundamental difficulties in establishing a consistent subdivision of personnel and graduates across all Nordic countries, but also due to insufficient time to collect the necessary quality indicators for scientific publications. The multivariate analysis performed in the following corrects for the unobserved factors which are constant over time and specific to the each university (fixed effects regression). However, some unobserved factors vary over time and may cause the estimated parameters in the following to be misleading. The results should thus not be considered as final answers, but rather as questions that need further inquiry.

Some universities specialize in scientific fields where international journals are not frequently used as scientific outlet. Thus, a raw comparison of the number of publications as estimated here across universities which specialize in non-internationally oriented fields with universities which specialize in internationally oriented fields will give the misleading indication that internationally oriented universities are more productive. This problem may be reduced by using fixed effects regression, as data from Finland and Denmark indicate that the staff composition of universities on different fields is relatively constant. Thus, if one considers changes over time there is a possibility that the effects of different field specializations of universities are controlled for. This is also true for the different profiles of universities with respect to the types of education offered. However, the optimal way of correcting for the different scientific and educational specializations of universities is of course to gather the data and use it directly in the analysis. This has, however, been beyond the scope of this report.

The econometric specification of the relationship between input and output follows loosely Cherchye and Abeele (2005), but with sensitivity analyses for other types of specification. Cherchye and Abeele (2005) employ truncated regression techniques, where this paper employs OLS and fixed effects regression. We use these techniques as none of our universities report 0 publications, and hence the added precision by using truncated regressions should not be big.

Different specifications of the lag structure have been attempted. The models appears to fit better when publications is regressed on current unemployment and lags of graduates, staff and external funding. However, there does not appear to be great differences between using one and two lags of these variables, hence the first lag has been chosen to save degrees of freedom. The OLS regressions have been presented to summarize and test the findings of the previous chapter. To test for the importance of fixed effects, a random effects regression was run and a Hausman test performed. The Hausman test consistently rejects the random effects model in favour of the fixed effects model. In the following, the OLS regressions thus only serve as an illustration of how the bivariate correlations of the previous section carry over to a multivariate case. However, the parameter estimates of the fixed effects regression are the basis of our economic interpretations in the following.

Table 8.2 – Table 8.7, present all the results of the regression analyses on the pilot database. The only variable of interest which is significant in the fixed effects regression is the staff. In the log-linear specification this enters with a parameter of 0.82, which is not significantly different from a unit-elasticity. Thus, a one per cent increase in staff leads to a one per cent increase in publications. The fixed effect regression of publications per head on graduates per head, staff etc. finds a negative coefficient on staff. This indicates declining marginal product of university staff. Thus, both the results of Table 8.5 and Table 8.7 – taken at face value – indicate that there are no scientific economies of scale.

Table 8.2 Number of publications, Linear specification, ols

	Parameter estimate	Std. Error
Unemployment rate	-25.9256	8.7695
Graduates (t-1)	-0.0955	0.0360
Staff (t-1)	0.4145	0.0362
Staff (t-1)^2	0.0000	0.0000
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	3.0577	68.1443
Dummy 1999	(dropped)	
Dummy 2000	-36.8375	68.7967
Dummy 2001	16.5235	64.9191
Dummy 2002	40.2021	65.7875
Dummy 2003	25.0970	65.4650
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	-2.3865	1.3419
Dummy Finland	-119.6730	44.0195
Dummy Norway	-84.1100	94.0255
Dummy Sweden	50.5645	53.4270
Constant term	117.2746	93.1684

Source: Analyses on the pilot database.

Lagged values of the degree of external funding never become significant – not at one or two periods lag. There is much variation in the variable, and with the amount of data available it is difficult to extract the potential information in the variable. It may also be the case that there really is no statistical relationship between external funding and university productivity. The fixed effects regressions do not allow for the estimation of country effects, but the OLS regressions systematically find a negative dummy for Finland – the only significant country dummy.

Table 8.3 Number of publications, Linear specification, fixed effects

	Parameter estimate	Std. Error
Unemployment rate	-1.934	3.2299
Graduates (t-1)	0.0198	0.0217
Staff (t-1)	0.0840	0.0656
Staff (t-1)^2	0.0000	0.0000
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	-47.7794	16.3792
Dummy 1999	-34.9460	16.1364
Dummy 2000	-28.1913	14.4477
Dummy 2001	-1.3020	11.5592
Dummy 2002	-0.8450	9.9906
Dummy 2003	(dropped)	
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	-0.0576	0.6682
Dummy Finland	(dropped)	
Dummy Norway	(dropped)	
Dummy Sweden	(dropped)	
Constant term	388.2856	96.3036

Source: Analyses on the pilot database.

Table 8.4 Log of publications, ols

	Parameter estimate	Std. Error
Unemployment rate	-0.0887	0.0286
Log (graduates (t-1))	-0.9670	0.1408
Log (staff (t-1))	2.5056	0.1269
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	0.0271	0.2229
Dummy 1999	(dropped)	
Dummy 2000	-0.1666	0.2253
Dummy 2001	0.0366	0.2126
Dummy 2002	0.2081	0.2153
Dummy 2003	0.2188	0.2141
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	-0.0075	0.0044
Dummy Finland	-0.6605	0.1400
Dummy Norway	-0.0402	0.3081
Dummy Sweden	-0.2972	0.1799
Constant term	4.9390	0.4781

Source: Analysis of the pilot database

Table 8.5 Log of publications, fixed effects

	Parameter estimate	Std. Error
Unemployment rate	-0.0010	0.0145
Log (graduates (t-1))	-0.0195	0.1680
Log (staff (t-1))	0.8232	0.2769
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	0.0169	0.0659
Dummy 1999	(dropped)	
Dummy 2000	-0.0343	0.0675
Dummy 2001	0.0997	0.0641
Dummy 2002	0.1335	0.0665
Dummy 2003	0.1556	0.0717
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	-0.0033	0.0029
Dummy Finland	(dropped)	
Dummy Norway	(dropped)	
Dummy Sweden	(dropped)	
Constant term	-0.4110	1.9659

Source: Analyses on the pilot database.

Table 8.6 Publications per staff previous period, ols

	Parameter estimate	Std. Error
Unemployment rate	-0.01364	0.00417
Graduates (t-1) / head (t-1)	-0.20007	0.02195
Staff (t-1)	0.00004	0.00001
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	-0.00021	0.03333
Dummy 1999	(dropped)	
Dummy 2000	-0.01766	0.03366
Dummy 2001	0.00514	0.03177
Dummy 2002	0.02540	0.03220
Dummy 2003	0.02422	0.03204
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	-0.00086	0.00065
Dummy Finland	-0.14207	0.02122
Dummy Norway	-0.05141	0.04550
Dummy Sweden	-0.03345	0.02627
Constant term	0.49230	0.05424

Source: Analyses on the pilot database.

Table 8.7 Publications per staff previous period, fixed effects

	Parameter estimate	Std. Error
Unemployment rate	0.00005	0.00165
Graduates (t-1) / head (t-1)	0.00254	0.01996
Staff (t-1)	-0.00007	0.00002
Dummy 1996	(dropped)	
Dummy 1997	(dropped)	
Dummy 1998	-0.02658	0.00810
Dummy 1999	-0.02161	0.00806
Dummy 2000	-0.01926	0.00722
Dummy 2001	-0.00838	0.00581
Dummy 2002	-0.00699	0.00497
Dummy 2003	(dropped)	
Dummy 2004	(dropped)	
Dummy 2005	(dropped)	
Degree of external funding (t-1)	0.00000	0.00034
Dummy Finland	(dropped)	
Dummy Norway	(dropped)	
Dummy Sweden	(dropped)	
Constant term	0.36591	0.04426

Source: Analyses on the pilot database.

The balance between economies of scale in research and knowledge dissemination

It is a widely held belief that economies of scale are an important prerequisite for success in science. For example, Denmark has recently launched a university reform with the clear intention of gathering related research and educational institutions in large units in order to create elite institutions. At the same time regional policy in the Nordic countries focuses to some extent on innovation as a key to regional development. The question is: What is the trade-off between concentrating resources in large units and transferring resources to regional innovation?

All the Nordic countries use innovation policy as a part of regional policy. In Denmark the government has launched a series of initiatives targeted at supporting innovation in the regions. The Ministry of Science, Technology of Innovations hosts 7 such initiatives: Regional Growth Environments, Crossroads Copenhagen, The Information and Communication Technology (ICT) initiative for Funen and Jutland, Regional Technology Centres, "Knowledge on the move" and the regional ICT initiative. The initiatives generally focus on the transfer of knowledge necessary for innovation to the regions. the instruments are cooperation between knowledge institutions, firms and knowledge dissemination institutes, pools of money for development projects, competence centres, regional development plans and analyses of regional strengths.

In Finland the government has launched the regional centres of expertise programme, which aims at supporting the specialization of the regions, improving their ability to attract funding for R&D activities, improve the coherence of regional and national policies etc. The main instruments of the centres are analyses of the regional strengths and opportunities, business development projects, knowledge transfer projects, activation of R&D activities of small and medium sized firms in their fields of expertise etc.

Norway also has a regional innovation initiative which supports projects and programmes with a focus on knowledge dissemination to the regions and regional innovation. The programmes support the adoption of new technology, improvements in companies' management, the use of ICT, the commercialization of knowledge etc. The instruments used encompass coordination and motivation of the regional actors as well as direct funding of innovative activities. The establishment of science parks is a visible product of the regional development activities.

Sweden employs a relatively decentralized approach to regional development, where the individual regions play an important role in the shaping of regional development policy. The areas of focus and the instruments thus differ from region to region. The regional development efforts are, however, coordinated by the agency Nutek.

Most of the policies of regional economic innovation and development have embodied in them evaluation procedures, and the programs and initiatives are being currently evaluated. However, for the purposes of this project it has not proved feasible to gather data to illustrate the importance of research institutions' knowledge dissemination activities. The primary reason is that the knowledge dissemination activities of research institutions are a fairly new phenomenon, and no consensus has been reached in the academic literature or at the research institutions themselves on how the results of these activities should be measured.

There is a relatively small literature which examines the effects of knowledge dissemination policies. Sørensen et al. (2005) found some evidence in favor of knowledge dissemination activities having an effect on private firms' investment in R&D. Adams et al. (2003) analyzed the effects of U.S. federal laboratory research on industrial research and found that the most effective instrument of knowledge transfer is explicit cooperative R&D agreements between industry and federal R&D laboratories. Recent research by Audretsch et al. (2005) found evidence that new high technology firms locate close to universities. However, the relationship depends on the type of knowledge: proximity to universities appear to matter most for firms which draw on nature science knowledge.

To summarize, there is some evidence that knowledge dissemination from universities can be important for regional innovation. It has not been possible to investigate the trade-off between economies of scale and knowledge dissemination, because the Nordic data on knowledge dissemination is not sufficiently readily available.

9. Conclusion – Part two

This part of the report has developed a design for a Nordic database on the inputs and outputs of Nordic research institutions, built a pilot database and applied it to analyze the effects of research funding structure and economies of scale on the scientific output of universities.

Based on the quality of the descriptive analyses of the pilot data, it appears that the data collected is indeed useful for addressing questions of the determinants of the output of universities: The data does not appear to be excessively noisy and when standard statistical techniques are applied to the data, some relatively consistent results arise.

However, the pilot database is not sufficient for providing definite answers to the questions of which is the optimal size of universities, what is the optimal structure of research funding etc. Developing the database as suggested in the design paper (appendix A) would greatly improve the basis for such analyses. Working with the pilot database has also revealed the need for an extensive standardization effort in order to make detailed data on the number of graduates and staff comparable across the Nordic countries. Furthermore, collecting the indicators of publication quality suggested in the database design will demand an extensive effort. On the basis of the work with the pilot database there is a collection of good experiences with such data – though of course they need to be much further refined.

The impression, which comes from performing statistical analysis on the pilot data, is primarily that there is no consistent support for the belief in the economies of scale in research. Analyses performed on Denmark, Finland, Norway and Sweden indicate that increasing the total number of staff cannot be expected to lead to a more than proportional increase in the number of scientific publications. If anything the opposite appears to be the case. The picture is clouded a bit by the fact that bivariate analyses based on Danish data indicate that if one focuses on the R&D personnel rather than the entire university staff, there does appear to be some economies of scale in research. The analyses in the present report also consistently fail to find a statistical relationship between scientific productivity and the structure of research funding.

The results should be interpreted with a great deal of caution, as they are based on an incomplete set of data. However, the collected data set is the first which allow statistical analysis of these issues in the Nordic context on a larger scope, and the results at least cast substantiated doubt on the hypothesis of economies of scale in research. The results also highlight the need for further analysis of the role of the structure of research funding. Though there are many good theoretical arguments of why external funding stimulates quality and quantity of research, the empirical analyses performed here cannot corroborate these theories. This in particular calls into question the emerging practice of evaluating research institutions on the basis of their ability to attract external funding.

Future work could use the pilot database as a starting point and supply the variables of the pilot database for Iceland as well. Furthermore, it would be very valuable to develop quality indicators of scientific publications by adjusting the publications in journal articles by e.g. the number of authors and the number of citations. Including monographs and anthologies in all Nordic countries into the database must probably wait a couple of years, as Sweden and Denmark are currently in the process of developing bibliometric tools for analyzing these kinds of publications. A fourth effort which would be valuable is the further refinement of staff and graduate data, which preferably should be made more comparable across countries.

Also, development on data on public research institutions' input and output would be most valuable: It would potentially allow for benchmarking of Nordic public research institutions, thereby improving the basis for identifying best practices. Furthermore, such an information system is an integral part of a Nordic research area.

Concerning the balance between knowledge dissemination and economies of scale, this report has not found strong evidence of economies of scale – but the data has some shortages with respect to drawing firm conclusions. On the other hand, there is some literature which points in the direction of knowledge spillover being important. However, the two factors should be investigated in a common framework to conclude which is most important.

Sammenfatning

Forskning og udvikling (F&U) opfattes i stigende grad som fremtidens vækstmotor i de vestlige lande. I en situation, hvor lavindkomstlande først og fremmest i Asien i stigende grad deltager i den internationale konkurrence på markedet for produkter med lavt vidensindhold, ser mange F&U som de vestlige landes store mulighed: F&U skal give de vestlige lande en konkurrencemæssig fordel inden for produkter med højt vidensindhold, og det skal bidrage til at undgå stigende ulighed som følge af, at konkurrencen bliver hårdere inden for produkter med lavt vidensindhold. De fleste undersøgelser finder også, at såvel private virksomheder, der investerer i F&U, som samfundet som helhed, opnår betydelige afkast af disse investeringer, jf. bl.a. Jones og Williams (1998), Wieser (2001) og Jensen et al. (2003). I de senere år er investeringerne i F&U også steget betydeligt i en række vestlige lande.

De nordiske lande satser alle til en vis grad på F&U, men der er store forskelle mellem udgifterne til F&U i de nordiske lande, og der er også forskelle på, hvordan de nordiske lande har indrettet deres vidensystem, jf. Nordisk Ministerråd (2005). For eksempel er de årlige udgifter til F&U i Sverige ca. 4 pct. af BNP, mens de i Danmark er ca. 2,5 pct. af BNP og i Norge ca. 1,7 pct. af BNP. Finland kanaliserer 42 pct. af de offentlige forskningsbevillinger gennem forskningsrådene, mens det kun drejer sig om 12 pct. i Danmark. I Finland tildeles 26 pct. af de offentlige forskningsmidler til industrien, mens det i Sverige kun drejer sig om 5 pct. Hertil kommer, at regionale hensyn spiller forskellige roller i de nordiske lande.

Spørgsmålet er, om disse forskelle i finansieringen af forskning betyder, at universiteter i nogle nordiske lande klarer sig bedre end universiteter i andre nordiske lande målt på videnskabelig produktion og uddannese.

Projektet tager udgangspunkt i resultaterne af forskningsindsatsen i de nordiske lande og analyserer arbejdsmarkedet for forskere i Danmark for at vurdere bidraget fra F&U værdiskabelsen i de nordiske samfund. For offentlige forskningsinstitutioner, hvis produktion ikke værdisættes på markedet, baseres vurderingen på en mængde indikatorer, herunder antallet af videnskabelige publikationer og antal forskeruddannede. Indikatorer for output vil blive sat i forhold til den ressourceindsats, der ydes på forsknings- og udviklingsområdet for at vurdere effektiviteten af indsatsen.

Rapporten er opdelt i to dele.

Den første del analyserer arbejdsmarkedet for forskere i Danmark med henblik på at vurdere, hvorvidt stigninger i investeringerne i forskning og udvikling kan ventes at finde sted uden betydelige stigninger i lønningerne til forskere. Analyserne gennemføres på baggrund af et omfattende registerbaseret datasæt, hvor hele den danske befolkning følges fra 1997 til 2002, og hvor der haves oplysninger om demografiske, uddannelsesmæssige og økonomiske forhold for hvert individ. Effekten på en potentiel forskers løn af at skifte jobtype fra en ikke-forskningsmæssig jobtype til et forskerjob vurderes, idet der tages højde for en række andre personlige karakteristika.

Metoden vurderes at være hensigtsmæssig, idet der sker en række skift mellem forskerjob og ikke-forsker-job over tid, jf. Summary tabel 1, der viser, at ud af de personer, der i 2002 var beskæftiget med forskning, var 10 pct. beskæftiget uden for forskning året før.

Summary tabel 1 Jobtype for personer, der var forskere i 2002, pct. af forskere 2002

	1998	1999	2000	2001
Forsker	70,42	79,85	83,46	88,45
Teknisk personale	6,00	5,10	3,98	2,15

Kilde: Egne beregninger på registerdata.

Hvis der fokuseres på de forskere, der har en ph.d.-uddannelse, er der også et vist råderum (i 2002) for at flytte arbejdskraft fra ikke-forsker-job til forskning, jf. Summary tabel 2. Tabellen viser antallet af ph.d'ere, der er beskæftiget med forskning i 2002, og det samlede antal ph.d'ere inden for forskellige videnskabsgrene.

Summary tabel 2 Beskæftigelse af potentielle forskere, ph.d'ere 2002

	Naturvidenskab	Samfundsvidenskab	Teknisk videnskab	Sundheds-videnskab
Forskere	701	1636	729	2609
I alt	820	2071	805	3389

Kilde: Egne beregninger på registerdata.

Analyser af, hvordan lønnen ændrer sig for potentielle forskere, der skifter fra ikke at beskæftige sig med forskning til at beskæftige sig med forskning, tyder ikke på, at der er en signifikant lønstigning forbundet hermed. Dette resultat afspejler måske, at forskerjob indebærer mere frihed i arbejdstilrettelæggelsen eller andre ikke-pekuniære fordele, som højtuddannede medarbejdere tiltrækkes af i en situation med høje marginalskatter. Lignende resultater findes for personer med videregående uddannelser svarende til OECD's ISCED 5A niveau. Resultaterne tyder således ikke på, at forskerlønningerne vil stige markant ved en øget forskningsindsats i Danmark.

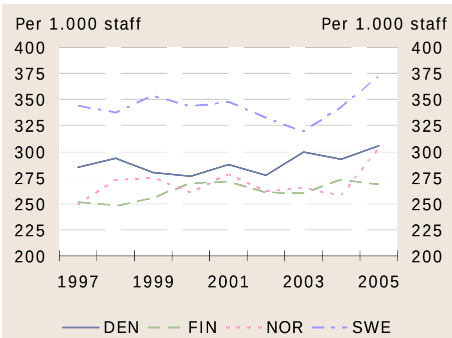
Der er to vigtige forhold, det er vigtigt at holde sig for øje i fortolkningen af ovennævnte resultater. For det første kan en øget forskerbeskæftigelse have afsmittende effekter på lønniveauet i ikke-forskerjob – hvilket indebærer, at en øget forskningsindsats kan forventes at medføre højere lønninger i resten af økonomien. For det andet belyser analyserne ikke, hvad der sker med lønningerne meget tæt på "kapacitetsgrænsen" på forskerarbejdsmarkedet.

I en situation med en mængde potentielle forskere, der ikke beskæftiger sig med forskning, tyder resultaterne af nærværende analyser dog på, at det marginale privatøkonomiske afkast af forsknings- og udviklingsaktiviteter i Danmark ligger i omegnen af 11 pct., jf. analyser af Nordisk Ministerråd (2005) og Graversen og Mark (2005). Internationale analyser af det samfundsmæssige afkast af forsknings- og udviklingsaktiviteter tyder på, at dette er meget højere end det privatøkonomiske afkast.

Rapportens anden del opstiller et forslag til en fællesnordisk database om offentlige forskningsinstitutioners output og input og indsamler data til en pilotdatabase med et udsnit af de centrale variable foreslået til den fællesnordiske database for universiteter i Danmark, Finland, Norge og Sverige. Endelig analyseres sammenhængen mellem forskningsinstitutioners input og output med fokus på betydningen af fordelingen af universiteters midler på eksterne og basismidler.

Summary figur 1 og Summary figur 2 viser udviklingen i to centrale variable over tid. Graferne viser en jævn stigning i universiteters produktion af kandidater og artikler i internationale videnskabelige tidsskrifter.

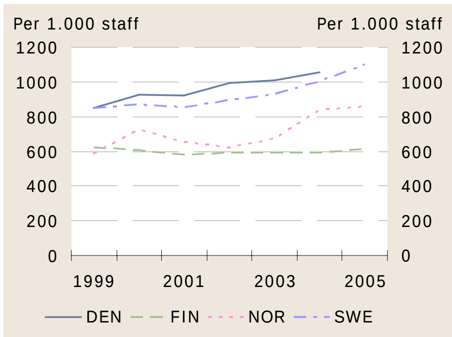
Summary figur 1 Artikler pr. 1,000 ansatte



Anm.

Kilde: Beregninger på Nordisk pilot database.

Summary figur 2 Uddannede pr. 1,000 ansatte

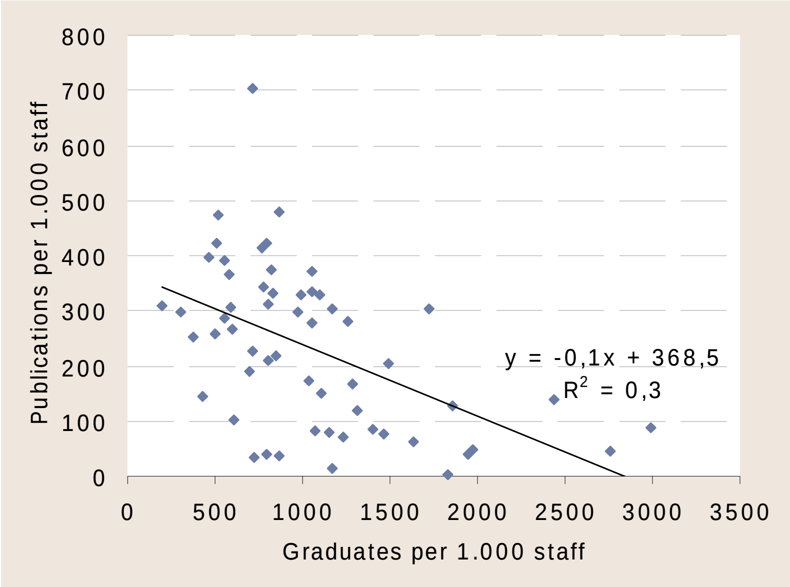


Anm.: Antallet af færdiguddannede er undervurderet i Norge, fordi Stavanger Universitet ikke indgår i datamaterialet.

Kilde: Beregninger på Nordisk pilot database.

På baggrund af oplysninger i databasen foretages forskellige analyser af betydningen af stordriftsfordele, finansieringsstruktur og afvejningen mellem produktion af uddannelse og videnskabelige artikler.

Summary figur 3 Sammenhængen mellem videnskabelige artikler og færdig-uddannede



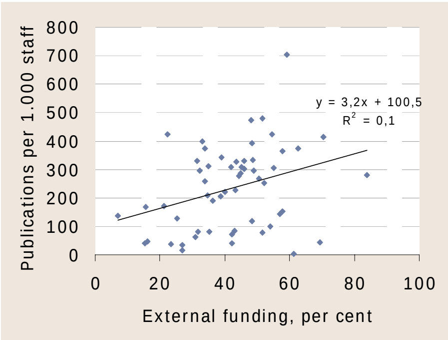
Anm.: De viste datapunkter er 3-årige gennemsnit af de relevante variable.

Kilde: Beregninger på Nordisk pilot database.

Summary figur 3 er et krydsplot mellem antal videnskabelige artikler og antal færdiguddannede på universiteter i Danmark, Finland, Norge og Sverige. I en bivariat analyse er der således en negativ sammenhæng mellem den indsats, der lægges i uddannelse og i forskning.

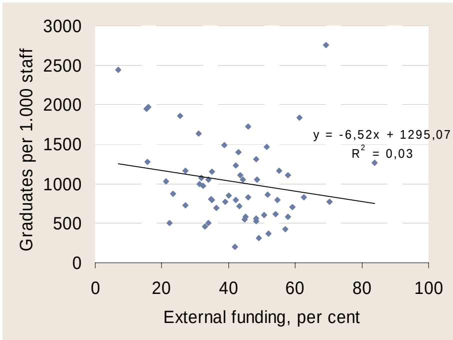
Summary figur 4 og Summary figur 5 illustrerer bivariate sammenhænge mellem henholdsvis antallet af videnskabelige artikler og antal færdiguddannede og graden af ekstern funding. Figurerne tyder på, at der kan være en positiv sammenhæng mellem graden af ekstern funding og antallet af videnskabelige artikler.

Summary figur 4 Videnskabelige artikler i forhold til ekstern funding



Kilde: Beregninger på Nordisk pilot database.

Summary figur 5 Færdiguddannede i forhold til ekstern funding



Kilde: Beregninger på Nordisk pilot database.

Bivariat analyse af sammenhængene mellem videnskabelige artikler, antal færdiguddannede og de færdiguddannedes ledighed indikerer omvendt ikke, at der er en sammenhæng mellem antallet af færdiguddannede og deres ledighed eller mellem antallet af publikationer og ledigheden blandt de færdiguddannede.

Multivariat analyse i form af OLS og fixed effect regressioner indikerer umiddelbart de samme sammenhæng som illustreret i ovenstående figurer, men i fixed effect regressioner bliver de fundne skøn ofte insignifikante.

Det mest konsistente resultat af analysen er, at der ikke kan findes tegn på stordriftsfordele i universiteternes videnskabelige produktion, men at det snarere er det modsatte, der gør sig gældende. Der kan ikke konstateres nogen statistisk signifikant effekt af finansieringsstrukturen.

Der bør udvises stor forsigtighed i fortolkningen af de empiriske resultater på baggrund af pilotdatabasen, idet en række centrale variable ikke er indsamlet til dette formål. De indsamlede data er imidlertid såvidt vides de mest omfattende oplysninger om nordiske universiteters videnskabelige produktion og input, og de usikre vurderinger må trods alt vurderes at hvile på et forbedret datagrundlag. Det kan anbefales at igangsætte en systematisk indsamling af data for offentlige forskningsinstitutioners output og input, da det vurderes at kunne forbedre beslutningsgrundlaget for forskningspolitikken betydeligt.

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Appendix A

Name	Year	Country	Staff	Publications	Graduates	External	Urate
Appendix table A.1 Danish data							
university of copenhagen	1997	DK	4599	1592	3534	28	5.537806
university of copenhagen	1998	DK	5024	1634	4258		4.744646
university of copenhagen	1999	DK	5201	1623	4405	33	3.625046
university of copenhagen	2000	DK	5201	1578	4749	34	3.180212
university of copenhagen	2001	DK	5212	1660	4400	38	4.971857
university of copenhagen	2002	DK	5203	1710	5258	33	6.076902
university of copenhagen	2003	DK	5215	1717	5043	31	5.31401
university of copenhagen	2004	DK	5333	1761	5375	30	.
university of copenhagen	2005	DK	5372	1805			.
university of aarhus	1997	DK	2931	1028	1773	36	5.942623
university of aarhus	1998	DK	3005	1085	2078		7.524454
university of aarhus	1999	DK	3019	1089	2416	28	4.967249
university of aarhus	2000	DK	3305	1101	2836	36	3.551402
university of aarhus	2001	DK	3104	1220	3055	39	4.399633
university of aarhus	2002	DK	3359	1193	3538	36	6.818182
university of aarhus	2003	DK	3410	1383	3518	37	5.86807
university of aarhus	2004	DK	3616	1285	3906	29	.
university of aarhus	2005	DK	3471	1386			.
university of southern denmark	1997	DK	1352	372	1159	32	7.210626
university of southern denmark	1998	DK	1290	457	992		6.148867
university of southern denmark	1999	DK	1758	487	1060	28	4.591837
university of southern denmark	2000	DK	1853	506	1838	35	4.812207
university of southern denmark	2001	DK	1827	475	1763	35	5.555556
university of southern denmark	2002	DK	1940	554	1902	39	7.089947
university of southern denmark	2003	DK	1973	602	1885	27	6.467181
university of southern denmark	2004	DK	2060	618	2047	31	.
university of southern denmark	2005	DK	2078	682			.
university of aalborg	1997	DK	1414	165	1450	33	4.347826
university of aalborg	1998	DK	1443	227	1384		6.648936
university of aalborg	1999	DK	1695	206	1545	34	4.660453
university of aalborg	2000	DK	1792	247	1695	25	3.990878
university of aalborg	2001	DK	1846	296	1728	23	5.860806
university of aalborg	2002	DK	1956	296	2065	26	11.25343
university of aalborg	2003	DK	2017	363	1958	19	10.92531
university of aalborg	2004	DK	2090	390	2249	19	.
university of aalborg	2005	DK	2094	431			.
copenhagen business school	1997	DK	995	32	1665	13	2.560819

copenhagen business school	1998	DK	992	32	1914		3.240324
copenhagen business school	1999	DK	981	33	1846	13	2.50298
copenhagen business school	2000	DK	987	26	1811	18	4.278729
copenhagen business school	2001	DK	933	35	1880	13	5
copenhagen business school	2002	DK	1109	35	2136	16	5.164835
copenhagen business school	2003	DK	1141	47	2275	18	6.666667
copenhagen business school	2004	DK	1200	56	2312	12	.
copenhagen business school	2005	DK	1235	54			.
roskilde university	1997	DK	684	84	1001	31	7.042254
roskilde university	1998	DK	672	78	987		4.057971
roskilde university	1999	DK	691	89	1050	29	4.447439
roskilde university	2000	DK	709	94	1166	30	2.888087
roskilde university	2001	DK	716	75	1334	24	5.925926
roskilde university	2002	DK	774	104	1404	29	9.84127
roskilde university	2003	DK	818	106	1543	25	10.81871
roskilde university	2004	DK	846	102	1576	22	.
roskilde university	2005	DK	851	104			.
technical university of copenhagen	1997	DK	2092	698	1023	30	3.909465
technical university of copenhagen	1998	DK	2071	715	1107		4.716981
technical university of copenhagen	1999	DK	2062	748	980	41	2.453988
technical university of copenhagen	2000	DK	2030	820	1004	41	2.886598
technical university of copenhagen	2001	DK	1986	803	857	46	3.289474
technical university of copenhagen	2002	DK	2218	797	938	50	7.524272
technical university of copenhagen	2003	DK	2174	852	1286	49	6.457926
technical university of copenhagen	2004	DK	2164	925	1415	46	.
technical university of copenhagen	2005	DK	2189	988			.
aarhus school of business	1997	DK	444	17	859	20	6.976744
aarhus school of business	1998	DK	443	25	820		4.6875
aarhus school of business	1999	DK	457	24	905	20	3.076923
aarhus school of business	2000	DK	482	19	834	16	5.357143
aarhus school of business	2001	DK	454	23	859	20	5.626598
aarhus school of business	2002	DK	524	19	950	17	8.454106
aarhus school of business	2003	DK	528	25	1035	16	5.744681
aarhus school of business	2004	DK	555	33	1192	15	.
aarhus school of business	2005	DK	563	40			.
Royal veterinary and agricultural university	1997	DK	1373	473	721	43	5.36193
Royal veterinary and agricultural university	1998	DK	1424	536	561		8.974359
Royal veterinary and agricultural university	1999	DK	1496	523	627	42	5.263158
Royal veterinary and agricultural university	2000	DK	1511	528	779	40	3.523035

Royal veterinary and agricultural university	2001	DK	1511	539	685	34	2.666667
Royal veterinary and agricultural university	2002	DK	1471	525	712	32	5.405405
Royal veterinary and agricultural university	2003	DK	1403	637	701	33	5.555556
Royal veterinary and agricultural university	2004	DK	1661	631	680	34	.
Royal veterinary and agricultural university	2005	DK	1662	585			.
university of pharma-ceutical sciences	1997	DK	253	132	135	32	5.154639
university of pharma-ceutical sciences	1998	DK	354	125	145		0
university of pharma-ceutical sciences	1999	DK	367	149	148	24	1.680672
university of pharma-ceutical sciences	2000	DK	360	137	174	39	3.076923
university of pharma-ceutical sciences	2001	DK	368	158	199	28	2.666667
university of pharma-ceutical sciences	2002	DK	350	148	172	20	3.361345
university of pharma-ceutical sciences	2003	DK	363	143	174	24	3.174603
university of pharma-ceutical sciences	2004	DK	374	170	205	23	.
university of pharma-ceutical sciences	2005	DK	372	151			.
IT university of copenhagen	1997	DK					.
IT university of copenhagen	1998	DK					.
IT university of copenhagen	1999	DK	16				.
IT university of copenhagen	2000	DK	65				0
IT university of copenhagen	2001	DK	85		42		5.12825
IT university of copenhagen	2002	DK	125		115	11	12.3805
IT university of copenhagen	2003	DK	159	22	237	18	9.30236
IT university of copenhagen	2004	DK	167	28	214	18	.
IT university of copenhagen	2005	DK	154	34			.
university of education	1997	DK			93		0
university of education	1998	DK			77		1.35131
university of education	1999	DK			96	46	2.27277
university of education	2000	DK			104	43	3.84614
university of education	2001	DK	310		106		2.45906
university of education	2002	DK	364		123	22	0.78742
university of education	2003	DK	467		202	28	5.66037
university of education	2004	DK	459	7	536	31	.
university of education	2005	DK	462	9			.
University of Helsinki	1997	FIN	6216	2204	3941	37.52092	4.76767
University of Helsinki	1998	FIN	6627	2280	3888	43.73714	3.18075
University of Helsinki	1999	FIN	6822	2362	3956	42.58914	2.62555
University of Helsinki	2000	FIN	6779	2465	4177	48.57348	2.43904
University of Helsinki	2001	FIN	6842	2519	4034	49.85381	2.27454
University of Helsinki	2002	FIN	7124	2446	4129	60.56997	3.170523

University of Helsinki	2003	FIN	7210	2453	4299	54.48312	2.878494
University of Helsinki	2004	FIN	7229	2768	4101	59.30088	.
University of Helsinki	2005	FIN	7403	2750	4289	59.84685	.
University of Jyväskylä	1997	FIN	1926	317	1489	32.45363	5.830389
University of Jyväskylä	1998	FIN	1983	348	1569	28.40437	5.459985
University of Jyväskylä	1999	FIN	2081	401	1578	30.91613	5.01699
University of Jyväskylä	2000	FIN	2141	435	1582	36.7229	3.48059
University of Jyväskylä	2001	FIN	2142	454	1597	48.7662	4.02955
University of Jyväskylä	2002	FIN	2200	462	1700	36.70252	5.773059
University of Jyväskylä	2003	FIN	2259	499	1784	36.44056	5.337423
University of Jyväskylä	2004	FIN	2309	475	1899	32.46714	.
University of Jyväskylä	2005	FIN	2368	478	1882	35.41026	.
University of Oulu	1997	FIN	2755	715	1457	42.58425	4.672131
University of Oulu	1998	FIN	2827	774	1530	30.49575	5.389718
University of Oulu	1999	FIN	2891	791	1557	41.76088	2.932551
University of Oulu	2000	FIN	2847	790	1500	44.91574	2.658789
University of Oulu	2001	FIN	2837	927	1466	48.60658	2.794562
University of Oulu	2002	FIN	2944	879	1494	47.25152	4.397271
University of Oulu	2003	FIN	2961	787	1558	39.38315	4.726736
University of Oulu	2004	FIN	2956	870	1619	45.77724	.
University of Oulu	2005	FIN	2956	874	1710	49.68123	.
University of Joensuu	1997	FIN	1104	175	758	26.53755	7.368421
University of Joensuu	1998	FIN	1165	181	811	27.69821	5.131965
University of Joensuu	1999	FIN	1148	166	801	30.08778	5.371901
University of Joensuu	2000	FIN	1116	208	784	25.58676	4.388298
University of Joensuu	2001	FIN	1111	235	813	28.52605	4.589708
University of Joensuu	2002	FIN	1174	229	849	34.29766	6.080207
University of Joensuu	2003	FIN	1245	262	832	36.36694	6.24235
University of Joensuu	2004	FIN	1245	237	845	35.90549	.
University of Joensuu	2005	FIN	1237	210	922	36.694	.
University of Kuopio	1997	FIN	1154	594	621	31.88966	4.474273
University of Kuopio	1998	FIN	1148	612	686	34.46973	3.269231
University of Kuopio	1999	FIN	1162	684	693	40.89604	4.074703
University of Kuopio	2000	FIN	1243	706	666	42.2958	2.184874
University of Kuopio	2001	FIN	1328	685	696	48.01614	2.460457
University of Kuopio	2002	FIN	1410	700	716	45.76565	3.146853
University of Kuopio	2003	FIN	1476	714	781	47.5814	2.31405
University of Kuopio	2004	FIN	1545	683	727	48.02776	.
University of Kuopio	2005	FIN	1523	757	863	49.0833	.
University of Turku	1997	FIN	2410	848	1501	39.72546	5.468103
University of Turku	1998	FIN	2588	757	1483	44.4988	5.202754
University of Turku	1999	FIN	2584	799	1498	46.0264	5.701425
University of Turku	2000	FIN	2234	895	1549	44.28472	3.440703
University of Turku	2001	FIN	2767	886	1535	39.44897	4.745042
University of Turku	2002	FIN	2711	829	1544	45.92403	4.737976
University of Turku	2003	FIN	2735	793	1552	44.78144	4.404332
University of Turku	2004	FIN	2745	848	1591	45.83197	.
University of Turku	2005	FIN	2697	866	1640	44.95922	.
University of Tampere	1997	FIN	1731	395	1334	32.97673	4.871568
University of Tampere	1998	FIN	1776	411	1519	34.24067	5.688889
University of Tampere	1999	FIN	1792	461	1489	41.54754	4.228487
University of Tampere	2000	FIN	1793	470	1429	38.25955	3.563129
University of Tampere	2001	FIN	1907	473	1445	42.14979	3.664495
University of Tampere	2002	FIN	2054	472	1478	43.89963	5.458861
University of Tampere	2003	FIN	2129	492	1514	45.23964	4.731861
University of Tampere	2004	FIN	2152	512	1579	41.9848	.
University of Tampere	2005	FIN	2120	451	1485	42.36907	.

Åbo Akademi (Swedish speaking university)	1997	FIN	1003	208	655	43.21574	3.742204
Åbo Akademi (Swedish speaking university)	1998	FIN	1054	272	634	45.01936	3.941909
Åbo Akademi (Swedish speaking university)	1999	FIN	1095	263	643	46.93194	2.538071
Åbo Akademi (Swedish speaking university)	2000	FIN	1127	251	654	50.60193	2.985075
Åbo Akademi (Swedish speaking university)	2001	FIN	1163	269	626	53.1333	1.663894
Åbo Akademi (Swedish speaking university)	2002	FIN	1184	282	747	51.47738	4.026846
Åbo Akademi (Swedish speaking university)	2003	FIN	1241	310	724	50.11338	3.034682
Åbo Akademi (Swedish speaking university)	2004	FIN	1219	348	751	51.09418	.
Åbo Akademi (Swedish speaking university)	2005	FIN	1233	328	741	50.67838	.
University of Vaasa	1997	FIN	390	9	336	30.85042	6.620209
University of Vaasa	1998	FIN	376	13	327	33.7385	4.444444
University of Vaasa	1999	FIN	382	7	359	22.3385	3.174603
University of Vaasa	2000	FIN	386	7	313	18.19903	2.601156
University of Vaasa	2001	FIN	376	9	344	13.44126	2.970297
University of Vaasa	2002	FIN	393	9	364	14.98046	5.688623
University of Vaasa	2003	FIN	424	18	384	20.47532	5.747126
University of Vaasa	2004	FIN	441	20	363	24.73778	.
University of Vaasa	2005	FIN	462	12	405	25.18332	.
University of Lapland	1997	FIN	490	9	374	21.84762	8.786611
University of Lapland	1998	FIN	555	14	349	17.76191	5.555556
University of Lapland	1999	FIN	594	14	373	23.41511	8.459215
University of Lapland	2000	FIN	556	8	420	46.57106	6.034483
University of Lapland	2001	FIN	534	13	391	27.22553	6.582278
University of Lapland	2002	FIN	578	14	402	27.2194	9.921671
University of Lapland	2003	FIN	600	24	420	27.26708	6.10687
University of Lapland	2004	FIN	606	19	442	25.86234	.
University of Lapland	2005	FIN	627	17	466	27.64116	.
Helsinki University of Technology	1997	FIN	2540	490	1114	48.57816	1.553829
Helsinki University of Technolog	1998	FIN	2665	496	1093	53.71576	1.139896
Helsinki University of Technology	1999	FIN	2880	580	1408	54.13651	1.230769
Helsinki University of Technology	2000	FIN	2974	620	1051	53.00977	0.920952
Helsinki University of Technology	2001	FIN	3023	668	1053	53.04784	1.151832
Helsinki University of Technology	2002	FIN	3104	704	1135	51.99997	2.505219
Helsinki University of Technology	2003	FIN	3160	817	1156	51.92901	2.119461
Helsinki University of Technology	2004	FIN	3191	798	1163	51.58477	.
Helsinki University of Technology	2005	FIN	3260	821	1254	52.55937	.
Tampere University of Technology	1997	FIN	1316	129	664	67.58511	1.697793
Tampere University of Technology	1998	FIN	1473	122	730	74.73236	0.492611
Tampere University of Technology	1999	FIN	1629	173	782	76.54197	1.335312

Tampere University of Technology	2000	FIN	1784	196	740	74.76218	1.879195
Tampere University of Technology	2001	FIN	1856	207	752	83.65802	1.709402
Tampere University of Technology	2002	FIN	1824	272	788	57.95061	2.51046
Tampere University of Technology	2003	FIN	1829	243	792	57.91407	2.759527
Tampere University of Technology	2004	FIN	1897	300	793	55.18469	.
Tampere University of Technology	2005	FIN	1906	265	829	58.05044	.
Lappeenranta University of Technology	1997	FIN	545	41	328	28.90771	1.582278
Lappeenranta University of Technology	1998	FIN	603	52	331	37.78478	1.923077
Lappeenranta University of Technology	1999	FIN	625	49	413	42.19789	3.15457
Lappeenranta University of Technology	2000	FIN	641	41	428	55.61843	3.21782
Lappeenranta University of Technology	2001	FIN	694	58	404	58.54607	3.60579
Lappeenranta University of Technology	2002	FIN	788	66	521	56.9377	6.940874
Lappeenranta University of Technology	2003	FIN	814	81	480	55.0625	4.313725
Lappeenranta University of Technology	2004	FIN	849	68	516	54.84197	.
Lappeenranta University of Technology	2005	FIN	869	107	552	52.19346	.
Helsinki School of Econ. and Bus. Adm.	1997	FIN	415	7	440	24.88884	0.811359
Helsinki School of Econ. and Bus. Adm.	1998	FIN	401	17	468	18.1621	1.272265
Helsinki School of Econ. and Bus. Adm.	1999	FIN	390	23	483	16.96598	0.443459
Helsinki School of Econ. and Bus. Adm.	2000	FIN	415	18	428	30.97298	1.4862
Helsinki School of Econ. and Bus. Adm.	2001	FIN	440	27	402	32.31817	4.076739
Helsinki School of Econ. and Bus. Adm.	2002	FIN	437	32	432	39.67978	2.544529
Helsinki School of Econ. and Bus. Adm.	2003	FIN	457	35	454	34.23143	2.369668
Helsinki School of Econ. and Bus. Adm.	2004	FIN	479	47	512	30.34201	.
Helsinki School of Econ. and Bus. Adm.	2005	FIN	499	35	580	30.83557	
Svenska Handelshögskolan	1997	FIN	237	12	224	25.05433	2.870813
Svenska Handelshögskolan	1998	FIN	228	11	195	25.93354	1.913876
Svenska Handelshögskolan	1999	FIN	219	16	235	23.88258	1.587302
Svenska Handelshögskolan	2000	FIN	214	20	229	30.44528	0.442478
Svenska Handelshögskolan	2001	FIN	214	17	285	33.31699	1.363636
Svenska Handelshögskolan	002	FIN	220	9	350	33.28494	3.249097
Svenska Handelshögskolan	2003	FIN	210	18	228	43.50035	2.601156
Svenska Handelshögskolan	2004	FIN	224	22	258	34.89279	.
Svenska Handelshögskolan	2005	FIN	221	12	267	26.97074	.
Turku School of Econ. and Bus. Adm.	1997	FIN	242	3	220	39.11739	3.589744
Turku School of Econ. and Bus. Adm.	1998	FIN	250	11	247	50.16845	0.480769

Turku School of Econ. and Bus. Adm.	1999	FIN	274	10	259	57.37927	3.75
Turku School of Econ. and Bus. Adm.	2000	FIN	26	6	201	49.4878	0.8
Turku School of Econ. and Bus. Adm.	2001	FIN	283	16	222	49.59561	3.589744
Turku School of Econ. and Bus. Adm.	2002	FIN	314	18	210	49.53042	2.347418
Turku School of Econ. and Bus. Adm.	2003	FIN	305	11	271	39.11408	2.415459
Turku School of Econ. and Bus. Adm.	2004	FIN	327	17	246	44.57598	.
Turku School of Econ. and Bus. Adm.	2005	FIN	329	11	248	42.77967	.

Appendix table A.2 Norwegian data

University of Oslo	1997	NO	4538.8	1295	2694	29	5.725191
University of Oslo	1998	NO	4493.8	1448	2645		.
University of Oslo	1999	NO	4399.8	1458	2773	31	4.081633
University of Oslo	2000	NO	4544.52	1368	3508		5.113636
University of Oslo	2001	NO	4571.41	1507	3011	36	5.572755
University of Oslo	2002	NO	4765.75	1396	3184		.
University of Oslo	2003	NO	5080.16	1537	3174	35	9.693053
University of Oslo	2004	NO	5363.89	1540	4896		.
University of Oslo	2005	NO	5405	1868	4652		5.663189
University of Bergen	1997	NO	2421.5	717	1227	39	8.743169
University of Bergen	1998	NO	2468.6	753	1309		.
University of Bergen	1999	NO	2563.6	778	1255	39	9.969789
University of Bergen	2000	NO	2585.26	784	1785		6.050955
University of Bergen	2001	NO	2629.57	816	1627	36	5.789474
University of Bergen	2002	NO	2707.78	820	1526		.
University of Bergen	2003	NO	2767.21	899	1972	39	10.13699
University of Bergen	2004	NO	2849.64	938	1957		.
University of Bergen	2005	NO	2939.59	1103	2716		10.89918
NTNU	1997	NO	3112.8	705	2068	32	6.009615
NTNU	1998	NO	3159.4	719	1999		.
NTNU	1999	NO	3245.6	767	2060	29	6.176471
NTNU	2000	NO	3304.81	754	2650		6.442577
NTNU	2001	NO	3351.96	793	2485	37	9.198813
NTNU	2002	NO	3508.27	800	2392		.
NTNU	2003	NO	3814.27	794	2888	40	12.68293
NTNU	2004	NO	4153.81	871	3731		.
NTNU	2005	NO	4320.52	1040	3825		11.16625
University of Tromsø	1997	NO	1492	334	436	26	6.930693
University of Tromsø	1998	NO	1423.5	413	484		.
University of Tromsø	1999	NO	1483.1	402	531	28	2.797203
University of Tromsø	2000	NO	1528.48	367	706		10.09174
University of Tromsø	2001	NO	1576.88	409	688	29	11.45038
University of Tromsø	2002	NO	1646.34	431	659		.
University of Tromsø	2003	NO	1713.84	466	832	34	9.433962
University of Tromsø	2004	NO	1752.7	426	842		.
University of Tromsø	005	NO	1827.64	470	972		9.756098
University of Stavanger	1997	NO	536	25			1.886792
University of Stavanger	1998	NO	558	41			.
University of Stavanger	1999	NO	594.6	25			3.688525
University of Stavanger	2000	NO	626.69	35			4.666667
University of Stavanger	2001	NO	685.89	49	1368		3.821656
University of Stavanger	2002	NO	711.76	54	1508		.
University of Stavanger	2003	NO	752.48	63	2221		0
University of Stavanger	2004	NO	786.23	48	2496		.

University of Stavanger	2005	NO	809.78	98	2310		8.527132
University for Life Science	1997	NO	792.3	156	408	48	8.791209
University for Life Science	1998	NO	834.2	183	464		.
University for Life Science	1999	NO	826.9	196	443	46	5.714286
University for Life Science	2000	NO	830.79	194	475		2.061856
University for Life Science	2001	NO	824.96	236	430	43	5.16129
University for Life Science	2002	NO	849.17	208	428		.
University for Life Science	2003	NO	870.8	254	452	46	13.82114
University for Life Science	2004	NO	866.32	263	921		.
University for Life Science	2005	NO	874.11	348	787		8.965517
NHH	1997	NO	244	22	612	7	1.818182
NHH	1998	NO	281	29	568		.
NHH	1999	NO	272.1	27	591	9	4.109589
NHH	2000	NO	271.8	34	543		0.980392
NHH	2001	NO	277.53	27	594	7	5.6
NHH	2002	NO	282.3	38	530		.
NHH	2003	NO	300.7	35	687	7	13.38583
NHH	2004	NO	317.59	43	756		.
NHH	2005	NO	329.82	54	876		2.857143
Norwegian School of Veterinary Medicine (NVH)	1997	NO	340.7	102	85	41	3.846154
Norwegian School of Veterinary Medicine (NVH)	1998	NO	350.9	121	84		.
Norwegian School of Veterinary Medicine (NVH)	1999	NO	358	125	83	44	0
Norwegian School of Veterinary Medicine (NVH)	2000	NO	371.66	129	81		0
Norwegian School of Veterinary Medicine (NVH)	2001	NO	363.71	131	92	44	5.555556
Norwegian School of Veterinary Medicine (NVH)	2002	NO	366.7	137	84		.
Norwegian School of Veterinary Medicine (NVH)	2003	NO	394.64	113	86	42	0
Norwegian School of Veterinary Medicine (NVH)	2004	NO	406.65	116	85		.
Norwegian School of Veterinary Medicine (NVH)	2005	NO	425.59	152	73		0

Appendix table A.3 Swedish data

Blekinge Institute of Technology	1997	SWE	221				4.5
Blekinge Institute of Technology	1998	SWE	244				1.8
Blekinge Institute of Technology	1999	SWE	310		298		4.4
Blekinge Institute of Technology	2000	SWE	350		340	62.3	2.9
Blekinge Institute of Technology	2001	SWE	388	18	404	50	2.3
Blekinge Institute of Technology	2002	SWE	420	34	444	43.2	3.3

Blekinge Institute of Technology	2003	SWE	455	33	525	42.9	6.4
Blekinge Institute of Technology	2004	SWE	459	34	569	43.3	.
Blekinge Institute of Technology	2005	SWE	454	29	593	40.5	
Chalmers University of Technology	1997	SWE	2196	764			1.9
Chalmers University of Technology	1998	SWE	2341	811			0.8
Chalmers University of Technology	1999	SWE	2414	892	1532		0.6
Chalmers University of Technology	2000	SWE	2475	901	1457	72.4	1.9
Chalmers University of Technology	2001	SWE	2397	878	1540	73	1.3
Chalmers University of Technology	2002	SWE	2414	940	1583	72.9	4.2
Chalmers University of Technology	2003	SWE	2389	926	1722	71.4	4.6
Chalmers University of Technology	2004	SWE	2266	962	1713	70.9	.
Chalmers University of Technology	2005	SWE	2142	928	1783	68.8	.
Gothenburg University	1997	SWE	3949	1371			5.1
Gothenburg University	1998	SWE	4182	1298			4.1
Gothenburg University	1999	SWE	4105	1385	3670		2.5
Gothenburg University	2000	SWE	4173	1473	4530	45.6	3
Gothenburg University	2001	SWE	4358	1555	4064	48.3	3.6
Gothenburg University	2002	SWE	4439	1432	4034	48.6	4.3
Gothenburg University	2003	SWE	4566	1525	4327	50.5	4.5
Gothenburg University	2004	SWE	4654	1530	5214	47.8	.
Gothenburg University	2005	SWE	4455	1508	4819	47.3	.
Stockholm School of Economics	1997	SWE		77			1.1
Stockholm School of Economics	1998	SWE		70			0.7
Stockholm School of Economics	1999	SWE		91	280		0
Stockholm School of Economics	2000	SWE		81	253	70.1	0.6
Stockholm School of Economics	2001	SWE	277	81	266	80.5	2
Stockholm School of Economics	2002	SWE	266	62	247	85.3	5.4
Stockholm School of Economics	2003	SWE	264	69	263	83.6	2.5
Stockholm School of Economics	2004	SWE	239	65	303	82	.
Stockholm School of Economics	2005	SWE	224	69	341	86.1	.
Jonkoping University	1997	SWE	331	12			3.3
Jonkoping University	1998	SWE	351	5			3.8
Jonkoping University	1999	SWE	354	7	605		1.1
Jonkoping University	2000	SWE	392	9	709	71.9	1.7
Jonkoping University	2001	SWE	434	10	695	64.7	1.6
Jonkoping University	2002	SWE	629	16	1134	65.5	2.4
Jonkoping University	2003	SWE	657	30	1557	69.8	3
Jonkoping University	2004	SWE	656	24	1900	71.7	.
Jonkoping University	2005	SWE	632	33	1897	66.2	.
Kalmar University	1997	SWE	380	12			2
Kalmar University	1998	SWE	449	27			2.1
Kalmar University	1999	SWE	506	44	731		3
Kalmar University	2000	SWE	549	37	766	59.3	2.6
Kalmar University	2001	SWE	590	45	780	55.6	3.9
Kalmar University	2002	SWE	631	68	778	48.4	4.2
Kalmar University	2003	SWE	715	68	779	47.6	4.2
Kalmar University	2004	SWE	736	87	1029	48.6	.
Kalmar University	2005	SWE	714	100	1040	48.8	.
Karlstad University	1997	SWE	584	15			2.2
Karlstad University	1998	SWE	726	19			3.4

Karlstad University	1999	SWE	791	33	1063		1.6
Karlstad University	2000	SWE	815	44	1156	47.8	2.2
Karlstad University	2001	SWE	873	62	1139	45.5	3
Karlstad University	2002	SWE	1015	65	1245	42.4	4.7
Karlstad University	2003	SWE	1078	69	1399	42.4	3.7
Karlstad University	2004	SWE	1104	88	1471	43.8	.
Karlstad University	2005	SWE	1057	118	1663	42.5	.
Karolinska Institutet	1997	SWE	2696	2099			2.7
Karolinska Institutet	1998	SWE	3001	2165			2
Karolinska Institutet	1999	SWE	3049	2305	1877		1.1
Karolinska Institutet	2000	SWE	3203	2274	1719	54.5	0.5
Karolinska Institutet	2001	SWE	3307	2382	2087	55.8	0.6
Karolinska Institutet	2002	SWE	3436	2362	2195	60	0.6
Karolinska Institutet	2003	SWE	3450	2081	2197	59.6	0.9
Karolinska Institutet	2004	SWE	3482	2592	2395	58.3	.
Karolinska Institutet	2005	SWE	3511	2665	2829	59.3	.
Royal Institute of Technology	1997	SWE	2967	826			.
Royal Institute of Technology	1998	SWE	3092	928			.
Royal Institute of Technology	1999	SWE	3091	1000	2240		.
Royal Institute of Technology	2000	SWE	2938	1074	2243	62.3	.
Royal Institute of Technology	2001	SWE	2877	1106	2057	62.3	.
Royal Institute of Technology	2002	SWE	3002	1091	2290	63.9	.
Royal Institute of Technology	2003	SWE	3008	1034	2280	63.4	.
Royal Institute of Technology	2004	SWE	2907	1063	2485	63	.
Royal Institute of Technology	2005	SWE	2827	1175	2431	61.5	.
Linkoping University	1997	SWE	2555	870			2.3
Linkoping University	1998	SWE	2654	896			2
Linkoping University	1999	SWE	2701	892	2461		1.6
Linkoping University	2000	SWE	2778	846	2336	56.8	1.2
Linkoping University	2001	SWE	2837	1033	2429	58.3	1.7
Linkoping University	2002	SWE	3005	956	3102	56.2	3.2
Linkoping University	2003	SWE	3186	860	3531	56.1	4.6
Linkoping University	2004	SWE	3066	925	3583	55.3	.
Linkoping University	2005	SWE	3045	1032	3717	54.1	.
Lulea University of Technology	1997	SWE	1133	195			4.9
Lulea University of Technology	1998	SWE	1120	168			4.1
Lulea University of Technology	1999	SWE	1174	186	1036		3.5
Lulea University of Technology	2000	SWE	1258	202	1237	55.7	2.9
Lulea University of Technology	2001	SWE	1289	214	1397	56.1	3.6
Lulea University of Technology	2002	SWE	1371	213	1651	57.8	5.6
Lulea University of Technology	2003	SWE	1412	228	1567	58.8	6.3
Lulea University of Technology	2004	SWE	1393	204	1547	57.8	.
Lulea University of Technology	2005	SWE	1406	205	1563	56.6	.
Lund University	1997	SWE	5904	2348			5
Lund University	1998	SWE	5767	2440			4.2
Lund University	1999	SWE	5575	2462	4272		3.4
Lund University	2000	SWE	5629	2318	4180	51.9	2.7
Lund University	2001	SWE	5721	2436	3975	53.5	4.2
Lund University	2002	SWE	5972	2491	4300	55.7	4.9
Lund University	2003	SWE	6147	2372	4424	56.1	5.9
Lund University	2004	SWE	6102	2495	4679	53.3	.
Lund University	2005	SWE	5637	2679	5017	54.5	.
Malmö University	1997	SWE	43	188			1.6

Malmö University	1998	SWE	483	196			4.1
Malmö University	1999	SWE	744	236	1090		2
Malmö University	2000	SWE	829	299	1251	42	2.1
Malmö University	2001	SWE	917	280	1459	47.6	1.6
Malmö University	2002	SWE	1021	302	1716	45.6	2.5
Malmö University	2003	SWE	1152	336	1750	48.5	3.8
Malmö University	2004	SWE	1136	336	1930	46.9	.
Malmö University	2005	SWE	1094	350	2132	42.5	.
Mid sweden University	1997	SWE	825	17			3.2
Mid sweden University	1998	SWE	868	26			3.5
Mid sweden University	1999	SWE	931	49	1178		3.1
Mid sweden University	2000	SWE	990	92	1227	59.7	2.2
Mid sweden University	2001	SWE	924	90	1278	54.9	2.6
Mid sweden University	2002	SWE	949	69	1299	55.8	3.8
Mid sweden University	2003	SWE	958	68	1310	58.2	4.6
Mid sweden University	2004	SWE	935	72	1318	55.4	.
Mid sweden University	2005	SWE	974	81	1566	40.9	.
Malardalens University	1997	SWE	492	1			2.8
Malardalens University	1998	SWE	550	1			2.1
Malardalens University	1999	SWE	630	3	1196		1.2
Malardalens University	2000	SWE	684	2	1198	66.2	1.6
Malardalens University	2001	SWE	745	4	1406	66.8	3.4
Malardalens University	2002	SWE	805	4	1350	65.7	5.3
Malardalens University	2003	SWE	852	1	1366	56.3	5.6
Malardalens University	2004	SWE	887	2	1764	63	.
Malardalens University	2005	SWE	851	7	1619	64.9	.
Stockholm University	1997	SWE	3344	911			5.6
Stockholm University	1998	SWE	3403	914			4.3
Stockholm University	1999	SWE	3392	967	3148		2.8
Stockholm University	2000	SWE	3363	950	3321	41.4	2.7
Stockholm University	2001	SWE	3363	1003	3214	42	3.8
Stockholm University	2002	SWE	3523	993	3346	42.8	5.8
Stockholm University	2003	SWE	3514	1047	3679	44	5.6
Stockholm University	2004	SWE	3369	1090	3745	43.3	.
Stockholm University	2005	SWE	3353	1214	3854	43.1	.
Swedish University of Agricultural Science	1997	SWE	2959	693			4.2
Swedish University of Agricultural Science	1998	SWE	2928	785			4.5
Swedish University of Agricultural Science	1999	SWE	3024	782	617		4.1
Swedish University of Agricultural Science	2000	SWE	3061	771	987	51.4	2.5
Swedish University of Agricultural Science	2001	SWE	3049	761	779	48.1	3.2
Swedish University of Agricultural Science	2002	SWE	2976	727	749	50.6	2.7
Swedish University of Agricultural Science	2003	SWE	2908	831	855	51.4	2.9
Swedish University of Agricultural Science	2004	SWE	2724	829	844	48.2	.
Swedish University of Agricultural Science	2005	SWE	2616	786	837	47.4	.
Umea University	1997	SWE	2918	845			4.6
Umea University	1998	SWE	3070	920			3.5
Umea University	1999	SWE	3118	921	2609		3.7
Umea University	2000	SWE	3175	979	2723	38.8	2.6
Umea University	2001	SWE	3365	938	2961	40.5	3.1
Umea University	2002	SWE	3533	979	3307	42.9	4.8
Umea University	2003	SWE	3653	1032	3621	43.6	4.6
Umea University	2004	SWE	3562	908	3598	44.1	.
Umea University	2005	SWE	3486	1030	4031	45.2	.

Uppsala University	1997	SWE	4518	2190			3.5
Uppsala University	1998	SWE	4635	2132			2.8
Uppsala University	1999	SWE	4659	2249	3560		1.9
Uppsala University	2000	SWE	4694	2249	3579	48.2	2.4
Uppsala University	2001	SWE	4805	2343	3502	49.2	2.3
Uppsala University	2002	SWE	4862	2315	3793	50.2	3.2
Uppsala University	2003	SWE	5002	2267	4087	52.2	3.3
Uppsala University	2004	SWE	4939	2322	4088	51.6	.
Uppsala University	2005	SWE	4724	2451	4507	51.3	.
Vaxjo University	1997	SWE	380	7			6.5
Vaxjo University	1998	SWE	404	21			2.4
Vaxjo University	1999	SWE	528	261	1019		1.3
Vaxjo University	2000	SWE	596	33	987	29	2.3
Vaxjo University	2001	SWE	662	24	1007	29.9	3.5
Vaxjo University	2002	SWE	745	34	1113	34.1	3.5
Vaxjo University	2003	SWE	799	44	1237	33.5	4.5
Vaxjo University	2004	SWE	831	39	1252	28.6	.
Vaxjo University	2005	SWE	832	69	1539	31	.
orebro university	1997	SWE	666	8			5.5
orebro university	1998	SWE	720	16			3.8
orebro university	1999	SWE	703	34	1098		2.2
orebro university	2000	SWE	762	43	1072	45.4	1.6
orebro university	2001	SWE	866	65	1256	38.8	2.1
orebro university	2002	SWE	982	134	1476	40.1	3.6
orebro university	2003	SWE	1088	162	1485	39.9	3.8
orebro university	2004	SWE	1066	253	1402	39.5	.
orebro university	2005	SWE	1008	230	1812	36.4	.

Appendix B

A Nordic database on public institutions' research and development output and the determinants hereof

Research and development (R&D) has become a key priority area in public policy. A major reason for this enlarged role of R&D is that globalization presents the countries of Western Europe with a choice between on the one hand facing tougher competition in markets for traditional goods and services, or, on the other hand maintaining a technological lead through innovation.

Furthermore, the role of scientific research is currently in a flux. There is an increased demand for accountability and demonstration of value in public sector research. The political response to this has been on the one hand to redefine the task of universities and government research institutions to include "knowledge dissemination", and on the other hand to improve the incentives and possibilities of these institutions to engage in a broader range of activities than research and education. In general public research institutions engage in an increasing number of different activities, and it becomes increasingly difficult to monitor and manage the activities in order to meet society's needs.

There is a growing business involvement in research. This presents a new challenge in striking the proper balance – from society's point of view – between on the one hand freedom of research and publication, and on the other hand the business partners' specific needs and desire to obtain intellectual property rights.

R&D plays a key role in fostering innovation. Hence a key policy priority is the identification of the factors that determine the success of R&D institutions.

The measurement of success in the R&D sector is a complex task. Society is placing an increasing number of responsibilities with R&D institutions: R&D, teaching, knowledge dissemination to firms and the general public, contributing to economic growth, maintaining scientific ethics etc. Thus in reality R&D institutions pursue a wide range of objectives, and their success in achieving R&D objectives should be measured against the resources spent on pursuing R&D objectives. Measuring the amount of resources spent on all the different, and sometimes unclearly defined, objectives is difficult. Add to this the fact that different institutions have different academic profiles and hence produce R&D results in different ways. Some scientific disciplines produce books, some produce journal articles, some produce archaeological findings, some produce patents, etc. Last, but certainly not least, mapping the relationship between quantity of output and the (long run) value to society is an immensely complex task.

However, given the importance of R&D in the development strategies of the Nordic countries, we believe it is necessary to start development of statistical tools to analyze the determinants of effectiveness in R&D. Moreover, it is necessary to develop data which allow for the analysis of variation in R&D input and output both across time, institutions and countries.

To this end this project designs a Nordic database of R&D output and input and on the factors which affect the relationship between R&D output and input. The Nordic case is particularly interesting, because the Nordic countries to a large extent share the same objectives but differ markedly in the means used to achieve the objectives. For example, in Finland the lion's share of R&D funding is allocated through competitive mechanisms, whereas in Denmark the majority of R&D funding is allocated through non-competitive base funding.

It is important to distinguish between the analytical purpose of this database and a hypothetical purpose of R&D evaluation or benchmarking. A key design feature of the database is the panel structure of the data. For analytical purposes this allows for correction for unobserved heterogeneity, which is probably of great importance. R&D institutions are complex, and many determinants of R&D output are very difficult to observe. In this case having panel data is potentially very useful, because it allows for the correction for unobserved factors when evaluating the effect of R&D inputs on R&D output. Furthermore, the bibliometric indicators of R&D output are most useful when information for a range of years is available. The database is not designed for evaluation purposes or to rank R&D institutions because of the shortcomings of the information on determinants of output and of the bibliometric output indicators.

To support the development of the database, a pilot project encompassing some of the Nordic countries is developed. The pilot database has the dual purpose of testing the database design and to allow for preliminary analysis. Testing the database design is a crucial step in developing the database – it involves checking whether the existing data have a useful form, coverage and quality to include in a useful database. The performance of preliminary analysis can provide important directions for extensions of the database. Stated differently, the pilot database may not provide answers, but it may allow the analyst to ask important and relevant questions, which can inspire the development of the database.

The pilot database is the first pan-Nordic collection of information on the R&D inputs and outputs of universities. It makes it possible to address simple questions such as:

- Is it the case that universities in one Nordic country systematically publish more books, contributions to anthologies, international

scientific articles, and produce more graduates than universities in other Nordic countries?
- Is there a trade-off between the number of scientific publications and the number of graduates and the employment rate of graduates?
- What is the relationship between the quantity of scientific publications and the funding structure of universities?

Objective of the database

Box 0.8 Objective of the database

> The overall objective of the database is to allow for analysis of the determinants of quantity and quality of R&D output at Nordic public R&D institutions. The analysis made possible by the database should be relevant for practical R&D policy making

Perspective

The analysis of R&D is of fundamental importance for many reasons. First of all R&D plays an important role in fostering and facilitating innovation activities which are fundamental to economic and social development. Second, in countries where the public sector is involved in funding R&D activities it is important to develop tools which allow for the analysis of how to best design the public involvement and the benefits and costs of the involvement.

The objective of this database is to facilitate the analysis of both the effect of public financed R&D on economic activity and the optimal design of public involvement in R&D.

The Nordic perspective is important, as the Nordic countries share the same overall objectives of the public involvement in R&D, and employ the same overall instruments to pursue the objectives. However, the Nordic countries differ in the degree to which the individual instruments are used, c.f. e.g. Nordic Council of Ministers (2005). Therefore a Nordic database is a most valuable tool in analyzing the design of public involvement in R&D. Furthermore, the industrial structures of the Nordic countries differ markedly. Hence a Nordic database is a valuable tool in analyzing the effects of R&D on economic activity.

At the time of the inception of the database the Nordic R&D agenda is dominated by questions of

- how the dissemination activities of the public R&D institutions best can be stimulated
- which funding practices support quality and quantity of R&D most
- whether and how public R&D involvement should focus on strategic areas of R&D

These issues of course influence the mindset of the individuals who are involved in the design of the Nordic database on R&D output and its determinants. However, it has also been considered how the database could be made amenable to future extensions.

Key concepts in the statement of objective

Research and development (R&D)

Box 0.9 Definition of R&D

R&D is defined by the OECD (and UNESCO) as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to device new applications. R&D encompasses three subcategories according to OECD (2002): Basic research, applied research and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed at producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. In practice the many scientific works have characteristics of both basic and applied research, e.g. strategic basic research, and the boundaries between the different kinds of research are less clear. See e.g. OECD (2002) for an in-depth discussion of the definition or Calvert (2002) for a broader discussion of how to define R&D.

There is no clear-cut answer to the question of what constitutes science. Different answers can in fact be given, depending on the perspective one assumes. Science can be viewed as something that's part of society more broadly, something part of a social system and finally as a *structure of knowledge*[8] which is more closely linked to the definition we will employ in this project. Looking at science this way it is a special branch of knowledge, that's unique in its systematic approach and exigency concerning proof and critical scrutiny, utilizing tools such as deduction of empirical observations that must adhere to inter-subjectivity and meet the criteria of falsifiability in order to qualify as scientific knowledge. This, in turn, is the product of research and that scientific output can take a distinct, well-defined form, as in the case of a scientific article or a pat-

[8] http://www.hb.se/professionsuniversitet/dokument/vadarvetenskap.pdf

ent, or just add to the existing stock of scientific knowledge through either radical or incremental new insights.

What do universities mean when they refer to science?

Science is generally thought to be something measurable and tangible where man is seen as unraveling the mysteries of the universe. To what extent can then different institutions/ faculties be said to be involved in science or scientific research?

According to UNESCO, the definition of R&D is stated as: "Any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications[9]". In other words, R&D differentiates itself from mere knowledge by requiring an effort to devise new applications. Separate from science, but often related to it, are concepts such as invention and innovation, where the latter refer to new products that have a potential for generating commercial returns. Clearly, university institutions may not represent the most effective environment for creating the bridge between science, on the one hand, and inventions or innovations, on the other hand. A broad set of competencies and institutions become highly relevant in this context.

Furthermore, science originally referred essentially to the nature sciences, i.e., biology, physics and chemistry. Gradually, however, there has been a slide towards a broader connotation, with the term science applied within a range of faculties, probably as an instrument for gaining more credibility as science is associated with measurable hard facts. Previously, subjects such as the humanities had primarily been concerned with the creation and maintenance of knowledge. The scope of science has therefore been partly broadened, partly diluted, over time, a fact that we should recognize in the project and adapt to by applying measures which are in accordance with university methodology at each faculty.

R&D output

Box 0.10 Definition of R&D output

> R&D output is new knowledge and new applications, c.f. the definition of R&D in BOX 0.9.

The definition in BOX 0.10 follows directly from the definition of R&D in BOX 0.9.

Examples of R&D output are:

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[9] UNESCO Statistical Yearbook, UNESCO, Paris, 68 and 65, Chap. 5. (latest update March 12, 2003).

- Scientific breakthroughs documented in a scientific journal
- New applications in the form of new goods and services

There is a large literature on the definition of “new knowledge” and “new applications”. A classical discussion concerns whether an application must be new to the world, or whether it is sufficient that an application be new to a market or firm, c.f. e.g. OECD/Eurostat (1997) or European Commission (2004). Another question is whether the organization of existing knowledge in the form of e.g. survey articles constitutes new knowledge.

The definition of new knowledge

Knowledge is defined as statements that are true or false depending on whether reality is as stated in the claims. This broad definition does not require any kind of documentation or dissemination of knowledge, and tacit knowledge is knowledge just as codified knowledge is.

There is a wide gap from this definition of knowledge to something which is measurable. Knowledge in the broad definition above can be embodied in persons, in written works or in goods and services. Much knowledge is probably embodied in scientific researchers in the form of “negative results”, that is, knowledge about things which are impossible or hypotheses which have been proven wrong.

Practice in much work on R&D input and output is to follow the operational definitions used by the scientific community and the users of technological applications consider new. That is, if the publishers of scientific journals or books consider a particular written scientific work worth publishing, then it is for practical purposes considered to be new knowledge. The implicit assumption underlying this approach is that publishing companies maintain a sufficiently high standard when defining an outlet as “scientific”.

To apply this approach it is necessary to develop a list of publishers from whom journal articles and books etc. are considered to be scientific.

When the list of publishers is formulated it is possible to add an element of quality control by involving researchers from all scientific fields in the process. As an example, in Norway the list of scientific outlets is defined in an open peer-process and periodically updated.

The operational definition of new knowledge is akin to the “central assumption” of bibliometrics (van Raan (2005)): “scientists who have to say something important, do publish their findings in the open, international journal (‘serial’) literature.”

The problem with this approach is that many applications of the approach violate a fundamental precondition for measurement, namely that the item of measurement should be independent of the way it is measured. If new knowledge is defined as the scientific articles published in a selected set of academic journals, then researchers gain an incentive to publish their existing knowledge in the specific journals which have been defined as providing new knowledge. This problem is widely recognized in bibliometrics, c.f. Weingart (2005).

Another problem is that the approach relies on publishing activity in written works that are published by private firms or other actors which may have objectives which differ from the objective of ensuring scientific novelty. Particularly worrying is the heavy reliance upon the "monopolist citation data producer Thomson Science", which is a private company that develop citation data, lists of highly cited journals etc. In effect one single private company has tremendous impact on scientific standard setting around the world.

Notwithstanding all these problems, the approach suggested for the Nordic database on R&D output and the determinants hereof uses a list of journals from Thomson Science as starting point for the definition of a list of scientific journals. The reasons for this are mainly

It facilitates international comparisons: Thomson science reports publishing activity in a uniform way across countries

The approach is widely used, hence the database design is easy to explain and document to an international audience

As Thomson Science is the chosen international standard for measuring journal publishing activity, the Nordic database is joining up with an established standard and can benefit from future improvements of the standard.

The suggested approach to defining new knowledge has many problems, and it is stressed that public research institutions can produce valuable new knowledge in many other forms than written works. In effect the database thus only measures a few aspects of the new knowledge generated at the public research institutions. For some fields of science these aspects are very relevant and probably give a comprehensive indication of the production of new knowledge. For other fields the extent of scientific publication gives only a limited impression of the production of new knowledge.

Further details will be given in the section on measurement of R&D output.

The definition of new applications

Public research institutions in the Nordic countries are currently not much involved in devising new applications. The reason is probably that research institutions are not required by law to participate in these activities, but rather do it for money, for fun or to realize some scientific benefits. However, research institutions do participate in the development of new public and private services to a lesser degree, predominantly in collaboration with other public sector institutions. There is also a level of involvement in the development of new private services, mainly at the technical universities. Development of goods and services is considered in this database for two purposes:

Development activities of public research institutions bring value to society and should be included to give a comprehensive coverage of the outputs of public research institutions.

The boundaries between the public and private sectors are currently in a state of flux, and it may be that future legislation binds or encourages public research institutions to participate in development activities. This development is apparent in the USA and to some extent in Europe, where public R&D institutions are using patents to an increasing extent to reap the value of development activities, c.f. *Research Policy* vol. 35. It is not unlikely that Nordic R&D institutions will engage in more development activities in the future. This database should be ready for this.

As it is defined in Box 0.9, new applications is quite difficult to measure for some of the same reasons as new knowledge is difficult to measure. The definition in Box 0.9 does not require that R&D institutions introduce their new applications to the market or document them in the form of patents, scientific articles or other.

As it was the case with the definition of new knowledge, the practical approach to measuring new applications will be to consider the new applications that are put to use. Specifically, we shall consider new applications to be synonymous with innovation, that is: The transformation of an idea to a new or improved product which is introduced in the market, or into a new or improved process which is introduced into trade or industry or into improved public service.

Quantity and quality of R&D output

Box 0.11 Definition of quantity of R&D output

> The quantity of R&D output is the amount of new knowledge and the number of new applications.

The quantity of new knowledge as defined in Box 0.11 is impossible to measure, but the broad definition is nonetheless given in order to make clear which quantity we want to measure or indicate.

Box 0.12 Definition of quality of R&D output

> The quality of R&D output is the value to the world community of new knowledge and new applications.

This definition of quality of R&D output in BOX 0.12 differs somewhat from the philosophical meaning of the word, which is closer to the notion of attributes of characteristics.

The definition of quality of knowledge as given in BOX 0.12 is also very far from anything measurable, but as for the definition of quantity, it is stated thus in order to make precise what it is that we purport to measure. The term “value” means the amount of money or goods or services for which the R&D output can be exchanged. Thus, the quality of R&D output is the amount of money, goods or services which the world community is willing to forego in order to have the R&D output.

A more fundamental question is whether the less prestigious publications are a necessary prerequisite for the preparation of the best articles. That is: “mediocre” publications are important as a source of identification of the most important and fundamental scientific problems, which can be solved in the prestigious publications.

Furthermore, the academic career structure and the funding mechanisms of research councils and other external funding parties have a “winner takes all” quality, which creates large inequalities in the output of scientists. However, a large group of “losers” is necessary in order to provide a strongly competitive environment and foster quality and quantity of research.

Nordic public R&D institutions

Box 0.13 Definition of Nordic public R&D institutions

> The Nordic countries are Denmark, Finland, Iceland, Norway and Sweden. A public R&D institution is an entity which has as a primary objective to perform R&D, and which receives base funding from the public sector to pursue this objective. The R&D activities must exceed a minimum such that the share of R&D personnel (headcount) of total personnel exceeds 20 per cent of total personnel at the institution.

“Practical R&D policy making”

By practical R&D policy is understood policy that addresses well defined problems using well defined instruments. A well defined problem in research policy could be that research does not have any identifiable impact on private sector activity, for example, that domestic firms have no research activities related to public sector research. Another well defined problem could be that domestic researchers cannot produce valuable research, that is, research which is judged by peers to be so interesting that it is worth publishing and reading. Well defined instruments are for example the level of funding given to research, the formal competencies which university management is required to have and the formal reward mechanisms available to the university management.

Data quality and applicability

The main objective can be split into some sub-objectives

- Comprehensiveness: All aspects of research output and its determinants, which are relevant for practical policy making should be covered (data validity).
- Flexibility: Data for research performing entities from all Nordic countries should be able to enter on a fully comparable basis at some stage. It should be possible to extend the database to include new data for future time periods and more objectives of the research entities.
- Reliability: The indicators which form the database should be able to be reconstructed by any other skilled researcher on the basis of the documentation of the database (data reliability).

Comprehensiveness

The database should cover all aspects of research output and determinants of research output, which are relevant for practical research policy. A relevant aspect is one which can at least in principle be influenced by public policy.

Flexibility

The database should be amenable to extension over time and the inclusion of further indicators of research input and output, and it should allow for the inclusion of data from all Nordic countries. This requirement is a natural one, given that this first effort of gathering this type of data will probably have some deficiencies: 1) pioneer efforts always (in hindsight) miss out something that coming generations of researchers and analysts find useful, 2) this project has limited resources, and given future resources for this data development purpose it would probably be possible to improve the database. Concerns about flexibility indicate that one should choose the university (or the entire research institution), the faculty or the individual researcher as the statistical unit, because institutes, departments and centres are often reorganized, and it may be difficult to track changes over time. However, it is necessary with information of the allocation of resources to the individual institutes because it allows for analysis of the advantages and disadvantages of concentration versus diversification of resources.

Reliability

This requirement is self explanatory.

Handling multiple objectives

The definition of R&D output precludes several activities of public R&D institutions and disregards some values provided to society by these institutions. For example, universities play an important role in the education of the population and in the dissemination of existing knowledge to firms, government and the general public. These services are valuable though they do not necessarily result in new knowledge or applications.

The role of public R&D institutions in disseminating knowledge to the community is fairly new. Presently there is no consensus as to which activities can be defined as dissemination. This implies that many or most Nordic R&D institutions do neither report their dissemination activities nor dissemination results, and among those that do report dissemination activities or results, reporting practices differ markedly.

The challenge is that R&D institutions expend resources in the pursuit of more objectives than just R&D. In order to make useful analysis of R&D output and its determinants, it is necessary to focus on the resources spent on R&D activities. This requires the identification of resources spent on non-R&D activities. Therefore the database will include a range of indicators of non-R&D output and non-R&D input.

The relevant aspects of R&D output and its determinants relate to society's gains from public R&D output and society's costs of public R&D efforts. One can use different approaches to evaluate society's benefits and costs of R&D. One approach is to consult the existing scientific literature in a search for scientifically established benefits and costs. Another approach is to read legal documents that state the objectives of R&D efforts.

On the basis of the first approach one could identify the following benefits and costs:

- public sector research stimulates innovation in the private sector, c.f. e.g. the survey by Hall (1996)
- public sector research improves the education of scientists and the general human capital level of the labour force, c.f. e.g. Hall (1996)public sector research stimulates innovation in the public sector
- public sector research stimulates regional economic activity
- public sector research involves real resource costs, as resources are spent which have alternative uses
- financing public sector research involves deadweight losses from taxation, c.f. e.g. Browning (1987).

The first approach has the advantage that it allows for welfare analysis. The approach can identify some societal benefits and costs of research and it can provide the basis for analysis of the factors that affect the benefits and costs. However, as the benefits and costs identified by the approach do not necessarily enter into the official objectives of research institutions, research managers cannot be expected to spend resources on maximizing the benefits and costs identified by the first approach. Thus, it is impossible to identify whether a possible lack of a statistical relationship between benefits and resource use is caused by bad structures in the research system or inappropriate objectives.

On the basis of the second approach one could find the following set of objectives can be found in Nordic laws, acts, performance contracts etc. of research institutions:

- Research (university act, act on government research institutes, performance contracts of university hospitals)
- Research based education (university act, performance contracts of university hospitals)
- Research at high international level (university act, act on government research institutes, performance contracts of university hospitals)
- Education of high quality (university act, performance contracts of university hospitals)
- Education at high levels (university act, performance contracts of university hospitals)
- Equal emphasis on research and education (university act)
- Dissemination of knowledge to the surrounding community (university act, act on government research institutes, performance contracts of university hospitals)
- Meeting ethical standards of science (university act, act on government research institutes, performance contracts of university hospitals)
- Consultancy to public sector (government research institutes)
- Governmental tasks (monitoring, statistical functions, …) (government research institutes)
- Development work with a societal purpose (government research institutes)
- Health care (performance contracts of university hospitals)
- Effectiveness (performance contracts of university hospitals)

The second approach has the advantage that it relates the goal achievement of research management or individual researchers with the resources available to research management. This allows for the identification of the effects of the constraints under which research management operates and the effects of structures in the research system on the goal achievement. The disadvantage of the second approach is that the official objectives of research managers do not necessarily coincide with the objectives which are optimal from the point of view of societal welfare.

The ideal approach would thus be to include in the database both a full set of official objectives, but also indicators of other social benefits and costs related to scientific research. This would allow for both the identification of the relationship between resource use and goal achievement, and of the relationship between resource use and societal welfare. The inclusion of other social benefits and costs will, however, await the development of data on the fulfillment of the official objectives and the analysis of this data. This analysis will most likely be useful in identifying other important factors to include in the database.

The database design will point out indicators of both the achievement of official objectives and of other possible benefits to society. In the pilot database, this project will start by collecting information on the official objectives of public research institutions and look for indicators of the achievement of these objectives and of the factors which affect the level of goal achievement.

The non-R&D activities of public research institutions, which are considered for the database, encompass:

- Education
- Dissemination
- consultancy for the public sector

Thus, the educational activities of universities and the consultancy and monitoring tasks of government research institutions are included in the database. Besides, knowledge dissemination is included as a separate non-R&D objective. The reason why these activities are included is that they involve an important element of knowledge transfer. Storage and archive-functions are not included. Hence, research institutions such as museums which act as archives or libraries are not included in the database. Furthermore, health care is not included and hence university hospitals do not enter into the database. Finally, monitoring activities are not included, as these activities have an element of repetitiveness and it is not clear that they contribute with any dissemination of scientific results or method.

Design considerations

Development of a database of R&D output and its determinants involves a range of strategic choices, among others: which types of objectives for R&D institutions should the database cover, what is the proper statistical unit, how should the definitions of e.g. science and R&D be made operational, which indicators of output and input are relevant and useful?

Statistical unit

- The chosen statistical unit must support the overall quality of the database and contribute to the overall fulfillment of the objectives of the database.

The statistical unit is the administrative unit at which the indicators of R&D output and the determinants of R&D output are measured. A public organization which produces R&D can be thought of as consisting of a number of administrative levels going from top management to the individual employee. Everybody which work in the R&D producing organization are associated with one administrative level and a corresponding set of powers and responsibilities. This is true regardless of the geographical location of the employees, the field of R&D etc.

The understanding of this project is that each R&D producing entity is embodied with a set of objectives and resources, personal as well as official, and faces a reward structure based to some extent on the degree of goal achievement. For example the rector of a Danish university has the official objectives that the university produces R&D and education and disseminates knowledge to the surrounding community. To achieve these objectives the rector can hire sub-managers, decide on parts of the internal organization of the university etc. The performance of the rector is rewarded through wage changes and through formal and informal prestige. There is reason to believe that the rector's personal objectives may deviate from the official objectives, which constitutes a principal-agent problem in the usual economic sense. Similarly the individual researcher has some official objectives such as R&D and teaching. The individual researcher has some time allocated to R&D and teaching, and has access to university resources as well as personal networks etc. As for the rector's case it is likely that the individual researcher also values time spent with the family, having fun while working etc., which may not lead to the attainment of official objectives. Thus, this project has focus on both the output of R&D, the resources devoted to R&D and the organizational features which affect the transformation from input to output. This means that it must be possible to link the statistical unit with information on the organizational resources under which the objectives are pursued.[10]

The chosen statistical unit should have R&D as one of its objectives, and it should be possible to collect information on the resources which the statistical unit spends on the attainment of all of its objectives. It is important that the R&D performance of the R&D institutions be measured against the resources spent on R&D, hence information on the resource use of the institutions is necessary. Indicators of the structure of

[10] This may not appear to have wide implications for the choice of statistical unit, but it does suggest that a ministry of science or a country as a whole serve as bad statistical units because it is difficult to identify objectives and organizational resources.

resource use could be either the number of R&D personnel years spent on education activities or other non-R&D activities. It could also be output indicators such as the number of graduates or the number of government reports produced, assuming there is a fixed relationship between resource input and the amount of these types of output.

The statistical unit is defined by a name.

Possible statistical units are the university, the faculty, the institute, the government research institution, the university college, the individual researcher, etc.

Desirable properties of the statistical unit are

- stability over time: the unit can be identified for an extensive period
- possibility of obtaining a representative sample with good data coverage
- the unit has an obligation to report high quality indicators of input and output to an official body

The individual researcher is a stable statistical unit over time, though some researchers change their name when married or for other reasons. Sub-units such as institutes, centres, departments etc. are the most unstable units, as they can be created or destroyed by decisions of university management. Government research institutions and university hospitals require decisions at the level of the minister and are fairly stable over time. Universities can only be created or destroyed by law and are the most stable units over time.

Box 0.14 The chosen statistical unit

> The statistical unit of the database is the university, the government research institution and the university college.

The choice of entire organizations as the statistical unit implies that the database will contain information on some very different entities. For example, some universities are active in only one scientific field, while others are active in several fields, some institutions are large, while others are small. Therefore it is important that the database contains comprehensive data on the input of resources in order to properly normalize the output indicators. Similarly it is important to consider closely the objectives and the profiles of the entities of the database in order to compare only comparable units.

Indicators of R&D output

Indicators of quantity of new knowledge created

Research takes many forms, as discussed above. Furthermore, different research units have different traditions for which form their output takes. The technical and nature sciences present their research output mainly in the form of articles in international peer-refereed journals. On the other hand the tradition among e.g. law departments is to publish mainly in national journals and in books.

The purpose of the database is to allow for analysis of R&D output and its determinants in all fields of science. This database borrows from the Norwegian experience on the development of a system of R&D evaluation and focuses on the following types of outlets: journal articles, monographs and contributions to anthologies. All the outlets considered must have either an ISBN or an ISSN-number, and they must have a tradition for peer review.

Peer review and the standards established in the R&D environment is the measuring rod which this database attempts to apply. The more stringent the peer review which has to be passed in order for publication and the more prestigious the scientific outlets, the more certain it is that a written work indeed constitutes new knowledge. This approach will also be used to evaluate the quality of R&D below.

A correction is made for the number of co-authors and whether authors are affiliated to several institutions. Perhaps the best way to explain the suggested method is by means of an example.

Box 0.15 Example of author-weighing of publications

Consider the journal article:

Assar Lindbeck, Sten Nyberg and Jörgen Weibull (1999): Social Norms and Economic Incentives in the Welfare State. *Quarterly Journal of Economics* 114(1), pp. 1-36.

The authors are/were affiliated to the following institutions:
Lindbeck: Stockholm University and I.U.I
Nyberg: Stockholm University
Weibull: Stockholm School of Economics and I.U.I

According to the suggested method of author-weighting, the institutions get the following article shares:
Stockholm University: 2/5 (1/5 Lindbeck + 1/5 Nyberg)
I.U.I: 2/5 (1/5 Lindbeck + 1/5 Weibull)
Stockholm School of Economics: 1/5 (1/5 Weibull)

Thus in effect there is defined to be 5 authors of the article: Lindbeck (Stockholm University), Lindbeck (I.U.I), Nyberg (Stockholm University), Weibull (Stockholm School of Economics) and Weibull (I.U.I). An institution's author share is the number of authors affiliated to the institution relative to the total number of authors.

This method of author-weighting has the advantage that it goes some way toward crediting an institution with the amount of effort the institution has put into developing new knowledge. The approach is not perfect, however: the working time of authors may be unevenly distributed between different institutions. For example, if an author works 1/3 of his time at one institution and 2/3 of the time at another, and the author publishes an article, then the institution which employs the author 2/3 of the time receives only ½ of the author shares. This is of course a problem. However, the problem is less than if no author-weighting were made.

Box 0.16 Measurement of quantity of new knowledge

> Quantity of new knowledge created is measured by weighted counts of written works in the form of monographs, contributions to anthologies and journal articles (articles, letters, notes, reviews).
>
> When an R&D institution's publications are counted, a correction is made for the number of co-authors. An R&D institution's share of a publication equals the share of authors who work at the given institution. Furthermore, if an author is affiliated to several institutions, the author's share is divided equally between the institutions.
>
> As a quality check, the lists of publications which forms the basis for the indicator should be quality checked by the individual R&D institutions.

The reason for focusing on these types of outlets are that new knowledge has to pass a peer review and the peer review is external to the R&D institution at which the new knowledge is generated.

This has the implication that the information in the database on new knowledge will reflect R&D activities which took place several years age, due to the publication lag.

Possible sources of information on research output are

- institutions' annual reports
- bibliometric databases, such as the Thomson Web of Science

Advantages of using institutions' annual reports are: 1) annual reports are typically required by law and specify a set of information that must be available for all institutions, 2) annual reports typically include a wide range of indicators of research output. Disadvantages of using institutions' annual reports are 1) that the typically are not available for a long period and 2) there are usually deviations in the way scientific output is reported for different countries and institutions.

Advantages of using the Thomson Web of Science are: 1) data is internationally comparable, 2) data is consistently reported for a long period, 3) the data encompasses information about co-authors and citations.

Disadvantages are 1) data only contains publications in journals, 2) only international publications are reported.

Box 0.17 Sources of data on output of new knowledge

Information on R&D institutions' publishing activity in scientific journals is gathered from the Thomson Web of Science in the following three databases:

- Science Citation Index Expanded
- Social Sciences Citation Index
- Arts and Humanities Citation Index

The following types of contributions are considered:

- Articles
- Letters
- Reviews
- notes

This information is supplemented by national data on publication in national or Nordic language journals.

Information on R&D institutions' publishing activity in monographs and anthologies is collected from institutions' annual reports and national databases. Denmark and Sweden: Institutions' annual reports. Finland: KOTA database, Norway: BIBSYS database.

A list of journals is developed for each country in an open peer process where participants from all scientific disciplines decide on a list of journals and book publishers in which publication of articles, contributions and books count as scientific publications. The list is periodically reviewed.

The Thomson Web of Science databases have important limitations. There is a good coverage of English language journals, which constitutes a large part all journals. But many publications are still published in other languages, which causes a bias. Therefore disciplines with a strong tradition of international publications, such as natural sciences and medicine, are favored, at the expense of nationally oriented fields such as social sciences and law. Besides, there is an important data cleaning task associated with making the Thomson database useful for counting R&D institutions' publications.

The database should attempt to correct for the shortcomings of the Thomson Web of Science is made by collecting information from R&D personnel in all scientific disciplines on the outlets used for written work. Measuring the scientific output by using counts of the different types of publications above does not per se allow for quality assessment of the scientific output.

Quality of new knowledge

R&D activities take many different forms, from applied research which can result immediately in the development new or improved goods to basic research which may no immediate application, but have great value for society in the long run. Measuring or indicating the quality or value of new knowledge is a therefore most complex task.

Nieminen (2005) summarizes these problems in the following way: “There is no ‘final’ or ‘objective’ way to define research quality, since it is a socially and culturally determined concept”.

Some attempts have been made in the science studies literature to more firmly establish the concept of quality. Gulbrandsen (2000) surveys the understanding of Norwegian researchers of the concept of quality. He finds that concepts such as “solidity”, “originality”, “scholarly/scientific relevance” and “practical/societal utility” appear to encompass the notion of quality. Hemlin and Montgomery (1990) understand quality as a notion more similar to the original philosophical definition, namely as encompassing both a value neutral description of aspects and an assessment of the value to humans of a piece of new knowledge. The value neutral aspects are e.g. method and theory applied, whereas examples of value assessments are utility of the contribution to science and society and the competence with which the contribution is presented.

A frequently used approach to define quality in an operational way is to rely on input from the academic profession to define different quality levels of scientific outputs. A conference of scientists from each scientific field thus convenes to define quality levels for their fields’ journals and book publishers.

When an employee at an R&D institution publishes a written work, it is categorized according to the peer-defined classification of publishers. An indication of the quality of new knowledge generated at an R&D institution is the share of high-quality publications of all publications.

If the highest prestige publishers tend to favor established researchers at the expense of younger or unknown researchers, there will be a bias in the suggested quality indicator. This bias may be reduced if the scientists are aware of the potential bias when they construct the list of high-quality publishers.

Another indicator of quality of new knowledge is the number of citations made by other scientists to a publication. This indicator has the advantage that it captures high quality of knowledge published by less prestigious publishers. However, though this indicator is informative, measuring the value of fundamental breakthroughs requires a long period of observation.

Box 0.18 Measuring the quality of new knowledge

The value of the new knowledge created is measured by:

Constructing lists of publishers of journals and books of particular high quality and of other quality levels. Journal articles, monographs and contributions to anthologies are categorized according to the quality level of the publisher. An indication of an R&D institution relative to other similar institutions is thus the balance between publications of different quality levels.

Counting citations of individual articles.

In order to count citations of articles it is necessary to define when a citation should count. It is suggested that a citation counts when it is made in the scientific outlets defined in BOX 0.17. Care must be exerted in counting citations, but the bibliometric literature has established some guidelines to how some of the problems can be avoided, c.f. e.g. van Raan (2005).

Box 0.19 Sources of data on the quality of new knowledge

The list of publishers of journals and books at different quality levels is constructed by a conference of scientists from the scientific fields. The basis of the decision could be a list of journals from the Thomson Web of Science combined with lists of scientific publishers or other sources of information depending on what the conference of scientists find necessary.

Presently there are only few organizations which have comprehensive information of the academic citation activity. One such database is the Thomson Web of Science, and there are a few others, but that basis for measuring citations in Nordic language publications must be developed anew.

Indicators of new applications

Recall from above that new applications are considered to be synonymous with innovation. This is done for practical reasons and not because it is believed that it is a negligible amount of new applications by R&D institutions, which are not introduced in the market or otherwise put to use.

The European Commission has put great effort into developing methods for measuring innovation. The results of this work are manifest in the Community Innovation Surveys, where firms and other organizations are interviewed periodically about their innovative activities, c.f. e.g. European Commission (2004). Guidelines for the measurement of innovation are given in the Oslo Manual, OECD/Eurostat (1997).

As it is the case for new knowledge we limit ourselves to considering new applications which take a specific form: that they have been introduced in the market or in an organization, or they have been documented.

One possible approach is to interview institutions whether they have introduced new products or services in the market or introduced new processes in their organization. Another possible approach is to apply indicators of innovation, such as e.g. patents.

An annual innovation survey can be performed for the Nordic R&D institutions, though the cost will most likely be relatively high. A survey can be performed as prescribed in the Community Innovation Survey. The advantages and drawbacks of survey methods to collect innovation data are described in a number of texts, e.g. OECD/Eurostat (1997).

It is also possible to use patent data from e.g. the European Patent Office (EPO) to construct an internationally comparable indicator of innovation for Nordic R&D institutions. The pros and cons of using patent data as an indicator of innovation are described in e.g. Pavitt (1985), Griliches (1990) or Hall et al (2001). The pros are primarily the wide coverage and wealth of information of patents, and the fact that the information contained in patents is provided voluntarily by the inventors. The cons are primarily that not all inventions are patented. In this context, patent data has the advantage that it already has been collected from EPO and cleaned for Denmark, Finland and Norway.

The quantity of new applications

Box 0.20 Measuring the quantity of new applications

> The quantity of new applications is measured by counting the number of patent applications by the R&D institutions. The source of information on patenting activity is the European Patent Office.

The quality of new applications

Box 0.21 Measuring the quality of new applications

> The quality of new applications is measured using patent citations and renewals.

Indicators of education output

Some R&D institutions supply education at different levels. Education contributes greatly to the economic welfare and growth in society by raising the productivity of the individual who receives education and indirectly of those who work together with the educated individual. Furthermore, education is a prerequisite for R&D.

The output of education is graduates at different levels. Thus, an indicator of the quantity of education output is the number of graduates at different levels of education. The disadvantage of this indicator is that different educations have different lengths and require different efforts to complete. Hence the same number of graduates from institutions in different countries may disguise important differences in the amount of education material that has been covered.

Another indicator of education output is the number of full time equivalents or "student years" produced in a year; this indicator summarizes the progress made by students at the research institutions. This indicator is robust to different educations having different length.

The primary purpose of including the education output is to be able to control for the amount of resources spent on producing education output in order to analyze the determinants of research output.

Box 0.22 Measuring the quantity of education output

R&D institutions' education output is measured by counting the number of graduates at different levels.

The number of full time equivalent students enters to the extent possible. The sources of information on education output are

- Denmark: Forskningsstatistikken developed by the Centre for Studies in Research and Research Policy
- Finland: Kota database
- Iceland: Statistics Iceland
- Norway: DBH database
- Sweden: SCB

Indicators of quality of education output

To measure the quality of the education output of different research institutions one should ideally address all the effects of education. The internal pecuniary effects are the only indicators of education quality, which it is realistic to include in the database. A possible indicator is the unemployment rate of graduates from the R&D institutions. Another possible indicator is the average wage received by graduates from the different R&D institutions. These two indicators give information about the labour market value of graduates at the R&D institutions. However, it is only possible to obtain information on the unemployment rate of graduates from the individual Nordic R&D institutions.

Box 0.23 Measuring the quality of education output

The quality of the education output of R&D institutions is indicated using the unemployment rate of graduates from the institutions.

The sources of the information are

- Denmark: Register data
- Finland: Kota database
- Iceland: Statistics Iceland
- Norway: Nifustep
- Sweden: SCB

Indicators of knowledge dissemination

Knowledge dissemination can take many forms, such as the direct collaboration with public and private organizations, the publishing of popular science literature, publishing of newspaper letter to the editor, giving speeches at non-academic conferences etc.

Presently the scope for including indicators of knowledge dissemination is limited, as most institutions have not developed systems for reporting dissemination performance, or the systems have only just been developed. Presently, however, there is no consensus about how knowledge dissemination activities should be measured, so different R&D institutions report different indicators. At present it is therefore not possible to include an indicator of knowledge transfer from R&D institutions in the Nordic countries.

Below is listed some possible indicators, that might be used at a later stage:

It is possible to use media search engines to identify personnel at R&D institutions who participate in the public debate. The number of appearances of personnel at an R&D institution in the media can thus act as an indicator of the dissemination activity. This task is quite laborious.

Furthermore, consultancy for the public or private sector has an element of knowledge transfer, and the number of consultancy reports written for private or public organizations or the revenue generated by such activities may be used as an indicator of knowledge dissemination.

Collaboration with other R&D institutions, education institutions, firms or other organizations may serve to disseminate knowledge, and some institutions report the number of e.g. joint ventures as an indicator of knowledge dissemination.

Consultancy for the public sector

Some R&D institutions have the important purpose of performing analysis for the public sector. Often these institutions also report the level of activity in this field in the form of e.g. reports.

Determinants of goal achievement

The determinants of the quantity and quality of R&D output, which are part of the database, should have a scientific foundation. That is, there must exist scientific publications which point to each determinant of R&D output, which is included in the database. The purpose of this restriction is to be able to abstract from a host of hypotheses without a theoretical or empirical foundation, so that the database can have a relatively lean design.

Some key determinants which have been established by the literature are, c.f. e.g. Stephan (1996), Lazear (1997) and Cherchye and Abeele (2005),

- the level of funding
- the structure of funding: base funding vs. competitive funding
- the input of personnel
- the composition of personnel: professors, associate professors,
- aministrative staff etc.
- R&D networks
- science base diversity
- the quality of student input
- the level of managerial competence
- the possibility of performance related pay

The level of funding affects the resources available for R&D, both in terms of physical capital or equipment, and in terms of the R&D personnel available. This also affects the R&D output quantity and quality. The structure of funding may also have an effect, as funding allocated on a competitive basis introduce an extra element of peer review and forces the individual researcher to consider carefully the project for which he or she applies for funding.

The input of personnel in terms of the total number of R&D personnel and the composition on professors, etc. naturally affects the quantity and quality of R&D. Research networks also constitute an important resource. R&D institutions which take part in many R&D networks have access to a broader and deeper knowledge base and have better possibilities for co-authored work, than R&D institutions which only use R&D networks to a limited extent.

Science base diversity may have an effect on R&D output, because it facilitates the cross-fertilization of ideas between scientific fields, as it has been explained in the case of cities by e.g. Jacobs (1969) or Duranton and Puga (2001).

The quality of student input is an important determinant of education output quantity and quality.

The quality of the organization at R&D institutions may play an important role for the level of output of such institutions, c.f. e.g. Stephan

(1996). The level of managerial competence in allocating personnel to different educational or R&D tasks may make a great difference to the quantity and quality of output. Also, the incentive structure formed by management of R&D institutions can be expected to affect the efforts of the personnel at R&D institutions and thereby also output.

Funding and personnel

The level of funding of institutions can be found in public finance laws or the annual reports of the public R&D institutions. The annual reports of the institutions typically also include information on the structure of funding, the input of personnel and the structure of personnel. This type of information can be found for long periods of time and is of a high quality. Furthermore, all the Nordic countries have special institutions which collect information on R&D expenditure and develop statistics on the subject. Hence, there is a wealth of comprehensive and high quality data on the income, expenditure and personnel of public R&D institutions.

The diversification of resources on academic fields is relevant due to considerations of the attainment of critical mass and to considerations of the importance of science field diversity. Indicators can be constructed using information on the number of employees working in different academic fields or the distribution of R&D institutions' resources on the fields. This kind of information is available in the institutions' annual reports and on the homepages of the institutions. The data covers only few years and not all institutions report information that can be used for this kind of analysis.

Box 0.24 Sources of information on funding and personnel

Information on funding is obtained from the following sources:
The sources of information on education output are

- Denmark: Forskningsstatistikken developed by the Centre for Studies in Research and Research Police
- Finland: Kota database
- Iceland: Institutions' reports and R&D statistics
- Norway: DBH database
- Sweden: HSV NU database

R&D networks

Information on research networks can be derived from the Thomson Web of Science from the co-authors of journal articles, letters, notes and reviews. From the individual articles the authors' affiliations can be obtained, allowing for the construction of indicators of the share of articles that are written in collaboration with national and international partners.

Care must be exerted in the use of research networks as an indicator of a determinant of R&D output, as the possibility of scientists to enter into R&D networks depends on the quality of their R&D output, so one should be wary of possible endogeneity problems.

Box 0.25 Sources of information on R&D networks

Data on institutions' participation in R&D networks is collected on the basis of information on the co-authors of the publications of institutions' personnel. The sources of information on institutions' publications are described in Box 0.17.

Student quality

The quality of student input can be indicated using international TIMMS data from the OECD.

Management quality

The only indicator which is available of management quality or power is a simple indicator of whether the management of R&D institutions is hired or elected by the peers.

List of variables and sources

All variables are covered for the period 1997–2005.

In the following the format of the variable descriptions is

- *Variable name* (short description)
  a) Extended description, possible values, and examples.
- *name* (Institution name)
  a) The name of the public research institution as stated in law, performance contract or other legal document defining the institution. Examples:
     i) Lund University
     ii) Norwegian School of Economics and Business Administration
     iii) Helsinki University of Technology
- *type* (Institution type)
  Type of research institution.
  Possible types are:
  a) *University*. A university is an institution which undertakes tertiary education (Type A, c.f. OECD), performs scientific research (c.f. OECD) and possibly other tasks. A university receives funding from the public sector to perform its tasks. A

university college is thus typically classified as a university according to this definition.

b) *Government research institute*. A government research institute is an institution which performs R&D and consultancy tasks for the public sector (and possibly others).

- *year* (Year)
  The year of the observation.
- *country* (Country)
  The country whose public sector defines the tasks of the institution.
  The value set is {Denmark, Finland, Iceland, Norway, Sweden}.
- *art* (Number of journal articles)
  This variable states the total number of journal articles published by authors who are affiliated with the particular R&D institution.
  The value set is 0,1,2,3,…,infinity.
  Journal articles are defined by one characteristic for the purpose of this database
  a) The articles are on published in a journal which is on a list of journal defined by conferences of scientists in the Nordic countries.
- *art1* (Number of journal articles level 1)
  The variable states the number of articles found by performing a specific type of search in selected international bibliographic databases, and which constitute the best selection of journals in the various fields as decided by national conferences of scientists.
  The value set is 0,1,2,3,…,infinity.
  Journal articles level 1 are defined the characteristic that
  a) The articles are on published in a journal which is on a list of the best 20 per cent of journals defined by conferences of scientists in the Nordic countries.
- *ashare* (The number of author shares of journal articles)
  This variable states the number of author shares of the R&D institution for the articles published by its scientists in the journal articles defined as in the variable *art*, counted as described in Box 0.15.
  The value set is [0;infinity).
  Journal articles level 1 are defined by one characteristic for the purpose of this database
  a) The articles are on published in a journal which is on a list of journal defined by conferences of scientists in the Nordic countries.
- *ashare1* (The number of author shares of journal articles level 1)
  This variable states the number of author shares of the R&D institution for the articles published by its scientists in the journal articles defined as in the variable *art1*, counted as described in BOX 0.15.
  The value set is [0;infinity).

Journal articles level 1 are defined by one characteristic for the purpose of this database

a) The articles are on published in a journal which is on a list of the best 20 per cent of journals defined by conferences of scientists in the Nordic countries.

- *antology* (Number of articles in edited works: edited books or conference books)

  This variable states the number of articles in edited books or conference books which have authors which are affiliated with the institution.

  The variable is calculated on the basis of national scientific sources:

  a) Denmark: University annual reports and annual reports of the government research institutions
  b) Finland: Kota database
  c) Iceland: Missing
  d) Norway: BIBSYS
  e) Sweden: ?

  and conferences of scientists in the Nordic countries define the set of publishers which produce works of sufficiently high quality to be included.

  The value set is 0,1,2,3,…,infinity.

- *anto1* (Number of contributions to antologies level 1)

  This variable states the number of articles in edited books or conference books level 1 which have authors which are affiliated with the institution.

  The variable is calculated on the basis of national scientific sources:

  a) Denmark: University annual reports and annual reports of the government research institutions
  b) Finland: Kota database
  c) Iceland: Missing
  d) Norway: BIBSYS
  e) Sweden: ?

  and conferences of scientists in the Nordic countries define the set of publishers which belong to the top 20 per cent of publishers in the fields.

  The value set is 0,1,2,3,…,infinity.

- *book* (Number of monographs)

  This variable states the number of monographs which have authors which are affiliated with the institution.

  The variable is calculated on the basis of national scientific sources:

  a) Denmark: University annual reports and annual reports of the government research institutions
  b) Finland: Kota database
  c) Iceland: Missing
  d) Norway: BIBSYS

e) Sweden: ?

and conferences of scientists in the Nordic countries define the set of publishers which produce works of sufficiently high quality to be included.

The value set is 0,1,2,3,…,infinity.

book1 (Number of monographs)

This variable states the number of monographs level 1 which have authors which are affiliated with the institution.

The variable is calculated on the basis of national scientific sources:

f) Denmark: University annual reports and annual reports of the government research institutions
g) Finland: Kota database
h) Iceland: Missing
i) Norway: BIBSYS
j) Sweden: ?

and conferences of scientists in the Nordic countries define the set of publishers which belong to the top 20 per cent of publishers in the fields.

The value set is 0,1,2,3,…,infinity.

- *antshar* (The number of author shares of anthology contributions)

  This variable states the number of author shares of the R&D institution for the articles published by its scientists in the anthologies defined as in the variable *antology*, counted as described in BOX 0.15.

  The value set is [0;infinity).
- *antshar1* (The number of author shares of anthology level 1 contributions)

  This variable states the number of author shares of the R&D institution for the articles published by its scientists in the anthologies defined as in the variable *anto1*, counted as described in BOX 0.15.

  The value set is [0;infinity).
- *bkshar* (The number of author shares of books)

  This variable states the number of author shares of the R&D institution for the books published by its scientists defined as in the variable *book*, counted as described in BOX 0.15.

  The value set is [0;infinity).
- *bkshar1* (The number of author shares of books)

  This variable states the number of author shares of the R&D institution for the books published by its scientists defined as in the variable *book1*, counted as described in BOX 0.15.

  The value set is [0;infinity).
- *graduate* (Number of graduates at master or bachelor level)

  This variable states the number of graduates (headcount and possibly FTE) of an institution.

  The variable is calculated on the basis of national sources.

  a) Denmark: University annual reports

b) Finland: Kota database
c) Iceland: Universities / Statistics Iceland
d) Norway: Norsk Samfunnsvitenskapelig datatjeneste
e) Sweden: HSV NU database

The value set is [0,1,2,3,…,infinity).

- *urate* (Unemployment rate of graduates)
  This variable states the unemployment rate of graduates from an institution.
  The variable is constructed on the basis of national sources:
  a) Denmark: Statistics Denmark, the register of the population's education and occupation
  b) Finland: Kota database
  c) Iceland: Not available
  d) Norway: Nifu Step
  e) Sweden: SACO
  The value set is [0;1].
- *patent* (Number of patent applications)
  This variable counts the number of patent applications to the European Patent Office by the R&D institution or employees at the R&D institution.
  The source is the European Patent Office (EPO).
  The value set is 0,1,2,3,…,infinity
- *patqual* (The quality of patents)
  This variable counts the number of citations made in other patents to patents issued to the R&D institution.
  The source is the European Patent Office (EPO).
  The value set is 0,1,2,3,…,infinity
- *staff* (Number of persons employed)
  This variable states the total number of employed persons (headcount) at the institutions.
  The variable is constructed on the basis of national sources:
  a) Denmark: R&D statistics at the Danish Center for Studies in Research and Research Policy
  b) Finland: Variably available in annual reports
  c) Norway: Norsk Samfunnsvitenskapelig datatjeneste
  d) Sweden: HSV NU database
  The value set is 0,1,2,3,…,infinity.
- *prof* (Number of professors employed)
  This variable states the total number of employed professors (headcount and possibly full time equivalents) at the institutions.
  Professor (or full professor) is the highest level academic title or occupation available.
  The variable is constructed on the basis of national sources:
  a) Denmark: Statistics Denmark, the register of the population's education and occupation
  b) Finland: Kota database

c) Iceland: Not available
d) Norway: Nifu Step
e) Sweden: HSV NU database

The value set is [0,1,2,3,…,infinity).

- *assoprof* (Associate professors)
  The variable states the total number of employed associate professors (headcount or possibly full time equivalents)
  The variable is constructed on the basis of national sources:
  a) Denmark: Statistics Denmark, the register of the population's education and occupation
  b) Finland: Kota database
  c) Iceland: Not available
  d) Norway: Nifu Step
  e) Sweden: HSV NU database
  The value set is 0,1,2,3,…,infinity.
- *assiprof* (Assistant professors)
  The variable states the total number of employed assistant professors (headcount or possibly full time equivalents)
  The variable is constructed on the basis of national sources:
  a) Denmark: Statistics Denmark, the register of the population's education and occupation
  b) Finland: Kota database
  c) Iceland: Not available
  d) Norway: Nifu Step
  e) Sweden: HSV NU database
  The value set is [0,1,2,3,…,infinity).
- *phdstud* (PhD students)
  This variable states the total number of PhD students at the institutions.
- *extern* (Share of external funding out of total R&D funding)
  This variable states the share of total university research funding, which comes from research councils, international organizations and industry. Some defining characteristics of this kind of funding are
  a) it is linked to particular activities or projects
  b) it is based on expected future performance
  The variable is constructed on the basis of national sources:
  c) Denmark: R&D statistics at the Danish Center for Studies in Research and Research Policy
  d) Finland: Available in annual reports
  e) Iceland: R&D statistics
  f) Norway: R&D statistics at Nifu Step
  g) Sweden: HSV NU database
  The value set is [0;1].
  The share of base funding is equal to 1- share of external funding.
- *divers* (Indicator of science base diversity)

This variable summarizes the distribution of the resources of the R&D institution on the different scientific fields. The index used is the following:

$$d_{it} = 1/\sum_{j} s_{ijt}^{2}$$

d is the level of diversity, *i* is the R&D institution, *j* is the academic field and *t* is time. The number of academic fields is 3: humanities and social sciences, natural and technical sciences and medicine.

The index is called “the Simpson index” by biologists, who often use the index to measure species diversity, but economists would probably consider it an “inverse Herfindal index”.

The value set is [1;3].

The sources of budget shares are:

a) Denmark: R&D statistics at the Danish Center for Studies in Research and Research Policy
b) Finland: Available in annual reports
c) Iceland: R&D statistics
d) Norway: R&D statistics at Nifu Step
e) Sweden: HSV NU database

elected (Indicator for whether the institution is managed by an elected or a hired manager)

This variable states whether the top manager of the institution is elected by the institution personnel or hired by an external body (e.g. the board of directors, the minister of education or other).

The value set is {0,1}.

The source is interviews with R&D institution heads.

network (The share of all publications co-authored with scientist from other R&D institutions)

This variable states the share of all publications in journal articles, monographs and anthologies, which are written by a scientist at the R&D institution in collaboration with scientists from other R&D institutions.

The source is the Thomson Web of Science and national sources as described above. The value set is [0;1].

Pilot database

The pilot database contains a selection of variables for a selection of the Nordic countries. The main limitation to collecting data is the lack of resources. In order to construct the variables *art*, *art1*, *antology*, *anto1*, *book* and *book1* it is necessary to invite conferences of scientists and define publications at different quality levels. This is not possible within the time- and budget framework of this project. Similarly, in order to construct the author weighted publications, *ashare*, *ashare1*, *antshar*, *antshar1*, *bkshar* and *bkshar1* it is necessary to count the number of authors of each publication, which takes too much time to be completed within this project. Patent information cannot be collected for this project either. This is also the case for the variable *network*.

The pilot database only includes Denmark, Finland, Norway and Sweden.

The list of variables included in the pilot database is thus:

- *name* (Institution name)
- *type* (Institution type)
- *year* (Year)
- *country* (Country)
- *article* (Number of journal articles)

This variable states the total number of journal articles published by authors who are affiliated with the particular R&D institution. For the purpose of the pilot database, the articles are found by searching in the Thomson Web of Science only.
Journal articles are defined by

The articles are found by a combined search for an institution name in the following ISI databases:

- Science Citation Index Expanded
- Social Sciences Citation Index
- Arts and Humanities Citation Index

The value set is 0,1,2,3,…,infinity.

antology (number of contributions to anthologies)
This variable states the total number of contributions to anthologies which are published by authors who are affiliated with the particular R&D institution. For the purpose of the pilot database, the articles are found by searching in the following databases:

- Denmark: Forskningsdatabasen
- Finland: Kota database
- Norway: Bibsys
- Sweden:

book (Number of monographs)
This variable states the total number of monographs published by authors who are affiliated with the particular R&D institution. For the purpose of the pilot database, the articles are found by searching in the following databases:

- Denmark: Forskningsdatabasen
- Finland: Kota database
- Norway: Bibsys
- Sweden:

graduate (Number of graduates at master or bachelor level)
urate (Unemployment rate of graduates)
staff (Number of persons employed)
prof (Number of professors employed)
assoprof (Associate professors)
assiprof (Assistant professors)
phdstud (PhD students)
extern (Share of external funding out of total R&D funding)
divers (Indicator of science base diversity)
elected (Indicator for whether the institution is managed by an elected or a hired manager)

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