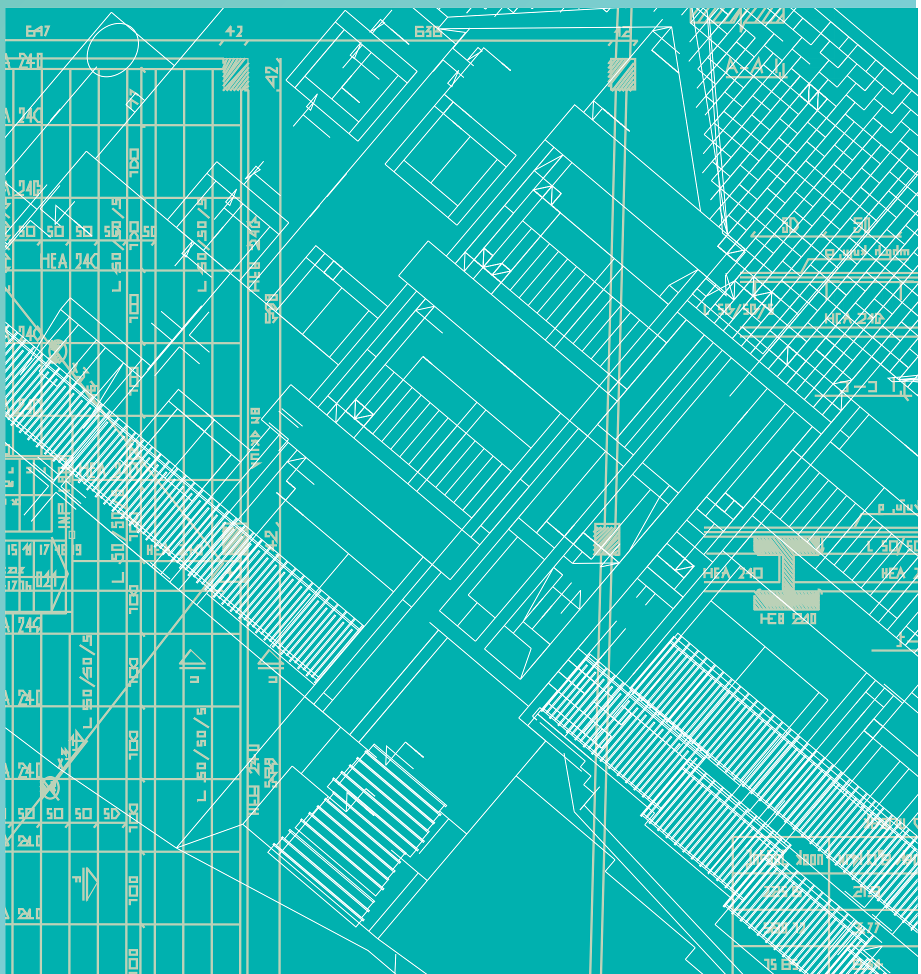
Analysis of the Danish Research and Innovation System

– A compendium of excellent systemic and econometric impact assessments



Ministry of Higher Education and Science
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Danish Agency for Science, Technology and Innovation

Analysis of the Danish Research and Innovation System – A compendium of excellent systemic and econometric impact assessments

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Foreword

When doing research and innovation analysis it is important to use methods that are based on proper scientific principles. It is, however also important to constantly challenge and develop the knowledge behind the methodology used to assess the research and innovation system. A sound knowledge of what works and what do not work is a condition for progress and we therefore need state-of-the-art econometric analysis for making qualified choices.

The compendium is an example of systemic analyses of the Danish innovation system and Nordic business investments in R&D. The two impact assessments are systemic rather than program assessments and they show the effect of investing in either corporate R&D activities or in the research and innovation system. The compendium consists of two new impact assessments and a new manual for carrying out high-quality analysis:

- *The Short-run Impact on Total Factor Productivity Growth of the Danish Innovation and Research Support System* – is a short-run impact assessment of participating in the Danish innovation and research support system.
- *Economic Impact of Business Investments in R&D in the Nordic Countries – A microeconomic analysis* – is an impact assessment of Nordic companies' investment decisions.
- *Central Innovation Manual on Excellent Econometric Evaluation of the Impact of Public R&D Investments (CIM 2.0)* – is a manual on how to carry out high-quality analyses.

Because of the constant need for qualified and state-of-the-art econometric analyses and evidence-based policy making there is an ongoing demand for updating the guidelines and procedures for evaluations and impact assessments. Therefore, the Danish Agency for Science, Technology and Innovation publish an updated version of the 2012-CIM manual for making excellent econometric evaluation.

The two system impact assessments make use of the guidelines in the CIM 2.0 manual and are examples of impact assessments which make use of excellent econometric methods. The assessments are possible because of the establishment of impressive and comprehensive national register data bases on firm R&D and innovation projects and activities as well as on firm panel data.

I hope the reader will find the new systemic analyses interesting and relevant and the compendium as exciting as we have. We encourage the reader to disseminate our work and to make active use of the CIM 2.0 manual in order to produce excellent impact assessment studies of their own and find inspiration to improve analytical methods and of attaining sound knowledge of econometric assessments.

Dr. Thomas Alslev Christensen

Head of Department, Danish Agency for Science, Technology and Innovation

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Foreword

As a new initiative, the Danish Agency for Science, Technology and Innovation has initiated a comprehensive impact study of the Danish system of innovation and support systems. This is possible because of the Innovation Danmark database which has a comprehensive amount of information about the innovation and support programs. With this new information available, we have an obligation to make use of the new opportunities that is provided to us for creating new knowledge; not only about the innovation system itself, but about the way we assess the system.

The comprehensive information from the Innovation Danmark database makes it possible to assess the innovation system, which is a rare opportunity. During the work with this report I have received very positive feedback from colleagues regarding the collection of information and the opportunities that this presents. Also when presenting drafts of this report I have received positive and impressed comments regarding the level at which we assess the Danish system of innovation and support systems.

This report is first and foremost a methodology report on the edge of the research frontier of impact assessments. We have accepted the new possibilities of assessing the system, by trying to clear the impact effect from other sources. Therefore I advise the reader to be careful when interpreting the results of the report and for a deeper analysis of the individual innovation programs; I refer to the individual impact assessments of the innovation programs.

I hope the reader of this report will find it as enlightening and inspiring as we have and will use this as an inspiration for further studies of impact assessments.

Thomas Alslev Christensen
Head of Department
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1. Introduction

This study performs the first joint estimation of the economic impact of innovation and research support programs. We focus solely on firms with less than 500 employees, and later restrict our analysis to firms with less than 100 employees.

This report features three important types of findings:

1) We quantify relative impact on productivity

2) We are the first who attempt to per form a causal study of multiple and simultaneous support programs[1]

3) We use the cleanest sample of participants and non-participants, to date, because for the first time we have access to extensive information about multiple program participation

We follow firms two years after participation, which is a short period. However, we have to make a compromise when aiming to cover as many programs as possible. This short window has two important downsides: 1) In programs, where we find higher productivity growth for participants, we cannot conclude on whether the effect on growth is a permanent effect, or 2) whether productivity growth rises in the short run because the participation effect induces a one-time lift to the productivity level.

Because we add strict criteria to avoid contaminated estimates, we perform our analyses on a sample of firms that most notably did not receive support two years before observed participation or two years following observed participation. These criteria apply to both participants and non-participants. We find that these criteria are necessary, as we wish to make causal inference on our estimates.

When estimating impact, we take into account the historical productivity performance of firms to rule out that firms participating were growing fast in the first place, and that we are simply picking a select group of firms that are growing faster.

Using our sample, we find that firms establishing contact with the support system, subsequently, on average, grow 2.5 percentage points faster annually the first two years, compared to non-participating firms. Behind this average estimate lies highly varying estimates for the individual programs.

Our main results (annual effects in percentage points) are that firms participating in *Innovation Network* (3.6), *Innovation Voucher* (3.6), and *Innovation Assistant* (2.9) tend to grow faster the first two years.2 The qualitative results are robust to alternative specifications, however, when we limit our analysis to firms with less than 100 employees and control for firm individual productivity growth trends (depending on firms size), we find that effects are larger for some programs. While *Innovation Assistant* effects are robust to alternative specifications, *Innovation Networks* (4.3) and *Innovation Voucher* (4.1) effects are amplified, and *Innovation Consortia* (4.6) now enters significantly in the analysis. All of these programs are designed spur an increase of knowledge via the channels collaboration, *counseling or within-firm skill upgrading*.

We find no enhanced productivity growth following participation in *Industrial PhD* (negative but insignificant impact), which is in line

__1__ Impact of several of the programs have been studied individually or grouped as for example "research projects". See e.g. CEBR (2009, 2011b, 2013a), DASTI (2011), DASTI & DAMVAD (2013), Kaiser & Kuhn (2012), and Chai & Shih (2013).

__2__ Results are from the instrumental variable approach in TABLE 5.2. Consult the table for significance levels.

with previous studies, and *Innovations Agents* (zero impact).3 The finding that Innovation Agents participation does not return differential growth is not surprising, but rather comforting. The *Innovation Agents* program is designed to give firms a "checkup" and then forward them to relevant private consulting or to other programs such as *Innovation Voucher*. One possible conclusion is that *Innovation Agents* check up on Danish firms with exhibiting productivity growth rates that are not different from that of the typical non-participating firm.

In the report we suggest other explanations for missing effects. One important circumstance is that this study does not look at productivity *levels*, only productivity *growth*. Thus, programs with no documented productivity enhancing effects may still play an important role by, for example, helping highly productive firms to expand product markets (possibly export markets) and thereby grow. This is, however, not within the scope of this study, but we encourage further studies into other performance measures.

The report proceeds as follows: Section 2 describes the different innovation support programmes. Section 3 presents the data and how we construct the sample, while section 4 explains the estimation method. In section 5 we present the main results (section 5.1) of our analysis as well as results using alternative specifications for robustness check (section 5.2), before finally discussing of our results (5.3). We conclude in section 6.

3 *We have somewhat few observations on Industrial PhD to firmly conclude. We have enough observations to conclude on Innovation Agents. Consult sections 3 and 5.1 for further information on which programs we have too few observations to conclude upon.*

2. Description of innovation support programmes

The description of the programmes contained in this section was written by The Danish Agency for Science, Technology and Innovation (DASTI).

Danish Council for Strategic Research

The primary focus of the Danish Council for Strategic Research (CSR) is to promote excellent and relevant research that will be of benefit to future development and economic growth in Denmark. Hence, the research must be of high standard and lie within areas of research that is related to societal challenges. CSR offers a number of different support programmes (including SPIR) aimed at both private firms and research institutions.

EUopStart

Danish firms and research institutions may apply the EUopStart programme for a grant (up to 20,000 euros) when applying for participation in selected European and international research programmes. The grants cover different activities related to the application process such as salary, travel, conference and consultancy. The receiving firm or research institution has to put down 50 percent of the grant in self-financing.

Industrial PhD

The Industrial PhD programme aims at increasing knowledge sharing between universities and private sector firms, promoting research with commercial perspectives, and taking advantage of competences and research facilities in private firms to increase the number of PhDs with knowledge about industrially focused research and innovation. For this purpose, the Industrial PhD student is employed in a firm and enrolled at a university at the same time. The student spends all his or her time on the project both places and shares his or her time equally between the firm and the university while taking the degree. The Danish Agency for Science, Technology and Innovation subsidises the Industrial PhD's salary with a fixed monthly amount and the expenses at the university with a fixed amount over the three years. A grant is approximately 134,000 euro divided between the firm and the university.

Eurostars

The Eurostars programme offers grants to small and medium sized firms (SME) and research institutions who participate in research and development programmes under the Eurostars programme. Hence, the Eurostars programme supports business-to-business cross border collaboration projects between enterprises from minimum two countries, and promotes market oriented R&D activities among research intensive SMEs. Grants amount to a maximum of 310,000 euros.

FP7

The Seventh Framework Programme is the European Union's chief instrument for public funding of research and for increasing private R&D. The Seventh Framework Programme is based on four principal programmes (Cooperation, Ideas, People and Capacities), with public sector bodies eligible to participate across all four. The major fields of research supported by the themes of the Cooperation programme are industry led and bring together public and private sector stakeholders to define research and development priorities, timeframes and action plans on a number of issues that are strategically important to achieving Europe's future growth, competitiveness and sustainability. The Marie-Curie actions funded under the People programme aims to increase mobility between public and private sectors, as well as between countries. To this end they will support industry training, joint research partnerships and staff secondments between the two sectors. As well as specific actions to help SMEs, the Capacities programme aims to develop European research infrastructures, optimise their use and improve access for researchers, including from industry. It will also support regional research-driven clusters, involving enterprises as well as universities and local authorities.

Research Voucher
The Research Voucher scheme was offered in the period 2008-2009. It provided support for research based collaboration between SMEs and knowledge institutions (Universities, RTOs etc.). The purpose of the Research Voucher scheme was to enhance innovation in SMEs as well as to make public research more application-orientated. The financial support was solely for the activities in the knowledge institutions, and could be up to a maximum of 200,000 euros for projects with duration of up to 2 years. The financial support could not surpass 25 pct. of the total budget for the project. Support was granted at a first come, first served basis. A total of 17 projects were initiated under the Research Voucher scheme.

Gazelle Growth
The Gazelle Growth programme helped small firms achieving their growth potential on foreign markets – especially the US-market. Due to the size of the home market, especially small gazelle firms from small economies have to look at foreign markets sooner than small gazelle firms from big economies, if they want to grow. That can be at a time, where their network and knowledge of foreign market can be limited. With the Gazelle Growth programme small gazelle firms was advised and trained, so the entry on a foreign market can go faster and succeed then if they tried themselves. The Danish Gazelle Growth programme was terminated by the end of 2010.

The Danish National Advanced Technology Foundation
The Danish National Advanced Technology Foundation offers private firms and universities the funds and the framework for developing new and important technologies. The general objectives of the Danish National Advanced Technology Foundation is to enhance growth and strengthen employment by supporting strategic and advanced technological priorities within the fields of research and innovation. Up to this day the Foundation has invested in 273 advanced technology projects with a total budget exceeding 700 million euros. Half of the finance comes from firms and research institutions themselves. Average support per project is approximately 1.5 million euros with a support range of each project from 0.5 to 12 million euros.

Innovation Agents
The aim of the Innovation Agents is to create innovation in small and medium-sized firms. Innovation Agents are public funded consultants that help firms identify barriers to innovation by performing an “innovation check”. The consultants identify the most important development opportunities for the firms and work closely together with regional growth houses and business advice offices to provide firms with one access point to the public innovation system.

Innovation Consortia
Innovation Consortia subsidies and facilitate collaboration projects between firms, research institutions and non-profit advisory and knowledge dissemination parties. The purpose of the programme is that the parties jointly develop knowledge or technologies that benefit not only individual firms but entire industries within the Danish business community. The joint projects should result in the completion of high-quality research relevant to Danish firms. Furthermore, the project should ensure that the new knowledge is converted into competences and services specifically aimed at firms, and that the acquired knowledge is subsequently spread widely to the Danish business community – including in particular

SMEs. A consortium can apply for financial grants at the Danish Agency for Science, Technology and Innovation, and the grants subsequently finance the expenses incurred by the research and knowledge institutions whilst undertaking the cooperative project. Typically grants amount to approximately 1-2 million euros.

Innovation Incubators

The objective of the innovation incubator programme is to promote commercialisation of new innovative ideas, inventions and research in particular through the creation of new knowledge based start-ups. The innovation incubators provide professional counselling and early stage gap funding (pre-seed and seed capital) for entrepreneurs and new innovative enterprises. The innovation incubators operate at the very early stage of the investment chain, where venture capitalists and other private investors are reluctant to engage. The innovation incubators funds 50 – 60 new knowledge based firms per year, and has a total budget of approximately 30 million euros.

Innovation Network Denmark (The National Danish Cluster Programme)

The Innovation Network Denmark programme supports the establishment of network and cluster organizations. An Innovation Network is a cluster organization with participation of all relevant Danish universities and technology institutes within a specific technological area, a business sector or a cross-disciplinary theme. Today a total of 22 innovation networks are scattered all over Denmark. Each network has pools for innovation projects where firms and researchers work together to solve concrete challenges. The innovation networks also carry out idea generation processes and matchmaking activities, and they hold theme meetings and specialist events. Hence, the overall objective for the innovation networks is to facilitate and encourage knowledge exchange between SMEs and knowledge institutions.

SPIR – Strategic Platforms for Innovation and Research

SPIR funds initiatives which seek to strengthen the link between strategic research and innovation and thereby promoting efficient knowledge dissemination and possibilities for fast application of new knowledge in connection with innovation in the private and public sectors. Typically grants amount to approximately 8 - 10 million euros.

Innovation Voucher

The Innovation Voucher scheme supports collaborative projects between a small or medium sized firm and a knowledge institution. The objective of the Innovation Voucher scheme is to encourage more SMEs to collaborate with universities, research and technology institutes and education institutions. The maximum amount of public support is 13,500 euro. The public support must not exceed 40 pct. of the total innovation project.

Innovation Assistant

The Innovation Assistant program provides an incentive for small and medium-sized firms to hire a highly educated person. The rationale is that highly educated people working on an innovative project promotes growth in the SMEs. The firm must have between 2 and 100 employees in order to receive subsidy (up to one year) to employ the highly educated person. Also the firm must pay at least half of the Innovation Assistants wages. Each grant is approximately 20,100 euro.

Open Funds

Open Funds where earmarked for innovative collaboration projects between firm and public knowledge institutions. The objective was to ensure that innovation projects that would benefit entire industries did not fall flat because they did not fit into the innovation system. Open Funds could finance up to 50 percent of a project. The programme was terminated in 2012.

3 Data

We use data from two different sources:

- The *Innovation Danmark* database created by the Danish Agency for Science, Technology and Innovation (DASTI) containing a list of firms that have received support (hereafter *participants*)
- Worker-firm matched registry data from Statistics Denmark

The databases have a common firm identifier that allows us to match the list of program participants with firm information. Firm information is crucial to performing impact assessment. We utilize information on value added, capital, number of employees, full-time employment, skills of employees, and industry (using the NACE3-classification)[4].

We have tried to combine the Innovation Danmark database with a different firm panel of annual reports data (Experian data, formerly also known as KOB-data). However, we are effectively able to match fewer participants using Experian data than through Statistics Denmark. Searching for missing matches after matching on firm identifier and year, is a much too comprehensive and ad hoc task for this project, as it involves searching through firm names in the panel data, or parts of names, from an extensive list of firm names that were not matched (either due to missing firm identifier (cvr-number) or, likely, mistyping in the Innovation Danmark database).[5] Why we find more mechanical matches using Statistics Denmark registry data, we cannot tell, because we do not control the data matching process (restricted for regulatory reasons to enforce anonymity of the firms in the registry data).

One advantage of Experian data over Statistics Denmark data is that it has one more year of observations (2012 over 2011). Some programs were introduced in later years, whereby adding one more year of observations would be very important to the analysis. However, due to the poor mechanical data match result, it does not add crucial information to the analysis.

For this analysis, we generally prefer data from Statistics Denmark to Experian data, because we can control for the skill of employees and use the effective size (full-time employment) of the firm level workforce instead of the number of employees. The skill level at participating firms is, on average, different from that of non-participants. Not controlling for the skill level introduces an upward bias on the impact assessment of productivity growth. Using the number of employees (the only available option in Experian data) instead of the fulltime equivalent number of employees (available in Statistics Denmark registry data) also creates a possible bias, because participating firms may differ from other firms in terms of the share of full time workers. Thus, we must compare firms using effective unit input of labor.

The Estimation Sample

Measuring productivity growth impact is not straightforward, because several circumstances affect firm performance. For instance, a natural bias of this sample is that we observe only firms that are neither bankrupt, bought up, nor reconstructed. We enforce strict criteria to isolate potential effects, implying that our sample shrinks from information of about 3,000 participation activities to about 1,100.

In this section we describe the process of creating the estimation sample(s). We illustrate the process in FIGURE 3.1 and TABLE 3.1, respectively.

__4.__The NACE-classification (Nomenclature statistique des activités économiques dans la Communauté européenne) is the EU stan-dard industry classification.

__5.__CEBR (2011b) focused on the Industrial PhD program and were able to recover a substantive number of missing observations.

We measure the impact of a particular program on firm performance relative to non-participating firms. We adjust the raw sample of firms from a set of criteria that are intended to center on capturing *participation effects*. Our point of reference is the *Raw Sample*, which is simply the result of matching the complete worker-firm panel of private Danish firms with the Innovation Danmark database. The raw sample spans from 2000-2011.

Using the full sample to measure these *participation effects* delivers an average firm performance difference between non-participants and participants. We control for a range of differences between firms based on statistical facts about the firms, and we leave out firms in industries where no participants are found. For an observation to be included we need a full set of information on each observation. The observations that fulfill the requirement of a full set of information make up the Estimation Sample.

We foremost use *Estimation Sample 1*, including all firms that have less than 500 employees and can be observed in a four year window.

Figure 3.1

Procedure to narrow the sample

Sample adjustment process	Adjustments made
Raw sample	
↓ Full sample	All firms with less than 500 employees and only from industries with program participants
↓ Estimation sample 1	Firms from the Full Sample that neither received support in the two years preceding the observation year nor in the two subsequent years
↓ Estimation sample 2	Same as Estimation Sampe 1 but for firms with less than 100 employees.

Notes: The figure shows the narrowing of the full sample of firms to comprise only relevant firms under stricter criteria.

The estimation samples are not just the result of mechanical changes to the data butalso the result of the chosen estimation strategy. The strategy imposes certain requirements to the data. We formally walk through the estimation strategy in section 4, but some of the criteria mentioned in this section are the result of the estimation strategy.

Using the same criteria as for *Estimation Sample 1*, we create *Estimation sample 2*, where the only altered criteria is that firm employment must be less than 100. We want to rule out as many biases as possible, i.e. in this case that firm size band is too wide. With so many programs and also repeated firm appearances in the support system we have to drop firm observations associated with participation before and after observed participation status in a given year.

TABLE 3.1 demonstrates how almost 11,000 observations of contact with the system in the Innovation Danmark database become about 1,100 observed participations in *Estimation Sample 1*.[6] We begin with the full Innovation Danmark database spanning from 2002 to 2012, imposing no criteria.[7] Here we have almost 11,000 observed participation activities from 8,300 firms. When we matched this data with the firm panel spanning from 2002 to 2011 (step 1 in TABLE 3.1), we drop more than 4,000 observations, most of which are from 2012.

We observe productivity growth development for two years. Thus, given that the last year of the sample is 2011, we can only measure impact on participation initiated no later than 2009. Therefore, we cut the number of observations in half to 3,100 by excluding information on support in 2010 and 2011 (step 2).

We limit our main analysis to firms with less than 500 employees, dropping more than 300 observations (step 3).

To measure productivity growth impact, we must observe productivity two years ahead and also other participation activity, dropping 800 observations (step 4).

6 *"Contact with the system" can refer to multiple participation in different programs within a year. However, this is rare.*

7 *After initializing this project, the database now contains information on some firms before 2002, and also current (not full) status for 2013 (constantly updated). The full sample refers to the sample of firms that Statistics Denmark was able to identify. CEBR has no control over this process due to data regulatory reasons. Firms are anonymous in the registry data and must remain so.*

Table 3.1

The effective number of participation observations in *estimation sample 1*

Steps	Criteria	First year	Last year	# obs.	# firms	# obs. /#firms	Revenue	Value added	Full-Time empl.
	None	2002	2012	10887	8307	1.310581	-	-	-
1	**Matched with registry data**	2002	2011	6409	4840	1.324174	449.0	149.0	249.4
2	**Effective event window**	2002	2009	3152	2488	1.266881	495.0	177.0	323.6
3	**Firms with less than 500**	2002	2009	2815	2357	1.194315	92.7	29.5	48.3
4	**Observations required (forward-looking)**	2002	2009	2022	1720	1.175581	109.0	36.8	55.0
5	**Observations about the firm historical growth**	2002	2009	1665	1424	1.169242	117.0	40.0	59.2
6	**Only firms not participating in two years before nor after observed participation status**	2002	2009	1096	1071	1.023343	94.5	32.0	46.2

Notes: The table step by step demonstrates each of the added criteria resulting in the final Estimation Sample 1.
Source: CEBR calculations using Innovation Danmark Database and Statistics Denmark registry data.

To control for historical productivity growth and participation activity adds further restrictions to the information criteria, dropping about 350 observations (step 5).

Finally, we restrict observations of participation to include only firm observations in those years where they did not receive support in the preceding two years and the following two years (step 6).

From TABLE 3.1 we observe that the number of observed participations across the 2002-2009 period is 1,096 split on 1,071 unique firms. Some few firms appear twice in the sample period. The 1,096 are indicative of activity.

Behind that aggregate number we find 1,140 individual program participation indications. These are shown in TABLE 3.2. Vertically the rows indicate the individual program. Horizontally, the columns indicate which types of programs fit into which group. We have seven groups but we include group 3 in group 2. Effectively, we can measure average group impact on group 2, 4, 6 and 7. Note that group 7 only comprises *Innovation Assistants*.

From TABLE 3.2, we see that the number of observed participations that fulfill all the necessary criteria to be included in *Estimation Sample 1* varies greatly from one program to another. For example, we have one observation of the *Danish Council for Strategic Research (DCSR),* but 327 on Innovation Networks. We are not able to make inference from the estimates of impact concerning participation in initiatives under *DCSR; SPIR, EUOpSTART and Eurostars* (all started recently); FP7 (started in 2007 and many applications made by large firms); *Research Voucher and Gazelle Growth* (few applicants, fewer observations); *The Danish National Advanced Technology Foundation* (effectively few observations).

Table 3.2

The effective number of observed program participations in *estimation sample 1*

	PROGRAMS GROUPS						
Program	1. Strategic research	2. Collaboration	3. Intl. collaboration	4. Counceling and support	5. Financing	6. Industrial PhD	7. Skill enhancing employment
Danish Council for Strategic Research	1						
EUopSTART				0			
Industrial PhD						51	
Eurostars			0				
FP7			14				
Research Voucher		2					
Gazelle Growth				10			
The Danish National Advanced Technology Foundation		11					
Innovation Agents				252			
Innovation Consortia		91					
Innovation Incubators					2		
Innovation Networks				327			
SPIR		0					
Innovation Voucher Scheme		180					
Innovation Assistant							167
Open funds		32					
GROUP TOTALS	1	136	14	589	2	51	167

Notes: The table shows the effective number of observations found in Estimation Sample 1 and used for the main analysis (see construction procedure above). The horizontal grouping of the 16 individual programs has been determined in collaboration with the Danish Agency for Science, Technology and Innovation.

Source: CEBR work on Innovation Danmark Database and Statistics Denmark registry data.

Next, in section 4, we present the estimation strategy.

4 Method

In this chapter we discuss in general terms the estimation methods used. The estimation design must suit the impact measure, in our case: Productivity growth differences between participating firms and non-participants, ruling out as many other factors as possible that may also have an impact, but founded on a well-formulated production function. Productivity is directly related to the availability of technology to a firm and the firm's ability to utilize the available technology. This is referred to as total factor productivity (TFP). To measure TFP we must specify a production function. However, by the estimation method that we choose, we obtain productivity growth directly from a transformation of the production function.

A widely used method for estimating participation effects of a single program is a twin study using a matching estimator. In this type of study, we match participating firms with, statistically speaking, twin firms that do not participate. This estimation procedure has some advantages over, for example, linear regression models. Communicating the analysis is reasonably straightforward: 1) A clear-cut control group of non-participating firms similar to participants is constructed. Thus, we can argue that any found effects are likely the true isolated effects of participation. 2) Given certain assumptions, we can conclude that the effect found is causal.

Given these clearly attractive properties of matching methods, we still cannot rule out a well-specified regression model, which is more flexible. One important downside of matching is that we match on level variables, which are "snapshot" characteristics, because matching on growth patterns preceding participation is very complicated. Thus we may be

BOX 4.1 PRODUCTIVITY GROWTH

When a firm uses inputs of production it incurs production costs. We can measure the total extra value created by the firm by subtracting production costs other than remuneration of capital and labor from revenue obtained from the sale of its production of goods or services. Economists refer to this extra value as value added. A firm can create more ***value added*** if it grows in size, for example by increasing capital use and/or hiring more labor. However, that does not per se imply increased production efficiency.

Often the public debate focuses on ***labor productivity***, which is simply valued added per employee. It is easy to calculate for descriptive purposes. However, labor productivity is indicative for comparing productivity differences across firms, industries (to some extent) etc. but does not take into account intensive use of capital. Thus, the productivity measure that we are interested in is one that takes into account the use of both labor and capital in production. Economists refer to this as ***total factor productivity***.

We measure ***total factor productivity growth*** as the growth in firm value added that cannot be attributed to increased use of capital or labor matching firms that at a snapshot in time have identical revenue, capital intensity, productivity level, workforce skill level, but actually follow two different dynamic paths. In such a case the firms are not suitable twin pairs to be compared.

The linear regression method (estimated using ordinary least squares, OLS) is still the best linear unbiased estimator available, and often we can justify that linearity of effects is a fair assumption. Measurement of growth differences is definitely such a case, and controlling for historical growth is uncomplicated, broadly used and well-described in the literature. Furthermore, we can specify our regression model and select our estimation sample such that any differences between a regression model and a matching procedure to assess impact of participation are, for practical purposes, eliminated.

4.1 Estimation

We rely on OLS estimation with fixed effects to estimate firm productivity growth from the firm level production function. Using this method, we can directly obtain a measure of participation effects from the estimates of productivity growth differences between participants and non-participants without having to estimate productivity separately for participants and non-participants in the first place.

We derive our estimating equation from a standard production function for firm i in year t:

$$Y_{i,t} = A_{i,t} K_{i,t}^{\beta_1} L_{i,t}^{\beta_2} \qquad (1)$$

Firm level value added, Y, is produced using capital *(K)* and labor *(L)* inputs, but also depends on firm level total factor productivity *(A)*. The total factor productivity level of a specific firm can be perceived as the result of available technology and its capabilities (e.g. strong management) to utilize labor and capital inputs. To see this, rewrite the production function to include firm i's individual productivity level component, c_i:'

$$Y_{i,t} = \left(c_i \widetilde{A_t}\right) K_{i,t}^{\beta_1} L_{i,t}^{\beta_2} \qquad (2)$$

Hence, firm level total factor productivity, $A_{i,t}$, is the scale product of cross-firm common technology $\widetilde{A_t}$ and firm individual ability to take advantage of common technology, c_i (i.e. the firm fixed effect).

Under the assumption that the above specification holds, each firm has an intrinsic productivity growth potential, because the individual component acts as a scale factor on firm productivity growth from changes in $\widetilde{A_t}$. This intrinsic ability of a firm to utilize available technology is unobservable. For shorter time periods we assume that this unobservable characteristic of the firm remains constant. Consequently, we focus on fixed effects estimation, which deals with time-constant unobservable characteristics. We therefore do not worry about the firm individual component c_i.

Taking logs of the production function (represented below by small letters) we can write up a basic estimating equation (leaving out potential control variables) for the production function:

$$y_{i,t} = c_i + \beta_1 k_{i,t} + \beta_2 l_{i,t} + \varepsilon_{i,t} \qquad (3)$$

Note the unobserved fixed effect of firm (i). We can remove the unobserved individual fixed effect by taking first differences (Δ), and when we then add some control variables and a participation indicator variable we arrive at our core estimating equation:

$$\Delta y_{i,t} = \alpha + \beta_1 \Delta k_{i,t} + \beta_2 \Delta l_{i,t} + \beta_3 education_{i,t} + \sum_{s=1}^{N} \gamma_s participation_{i,s,t} + \delta_j + \eta_t + \Delta\varepsilon_{i,t} \qquad (4)$$

We estimate the linear regression model above using pooled OLS.

8 Unless we specify another forward year, we always consider two-year forward differences.

Our dependent variable is Δy_t measured in log points between time t and t+2.[8] This gives us the percentage point growth in firm total value added. We account for the growth contribution to value added from increasing use of capital and labor resources.

We choose a two-year lead period for two reasons. First, we find one year to be too short, and second, we lose too many observations if we use longer lead periods.

An observable variable, which is an indicator for a firm's ability to absorb new technology, is whether the firm a priori is skill intensive. Our fulltime equivalent labor stock variable cannot be divided into different skill types of labor. Thus, to account for the fact that labor is a heterogeneous input, we introduce a variable accounting for the initial share of workers that hold at least a bachelor degree. Furthermore, we account for industry specific trends in productivity growth (δ_j), and time varying trends in productivity affecting all firms (η_t).

Apart from accounting for the initial relative skill level of firm labor stock, we do not add further level variables (such as size or productivity level) to our estimating equation, because we stick to our model specification, i.e. the production function. Adding further variables on an ad hoc basis distorts the theoretically motivated estimation strategy. As explained above, the share of high skill workers is justified from the criteria of acting as a proxy for labor quality. In section 5.2 we perform robustness checks, adding level control variables.

We measure whether an average trend difference in Δy_t exists between firms receiving support and firms not participating. Thus, we obtain an estimate of potential participation effects from the coefficient(s) γ_s on the participation indicator variable(s) ($participation_{i,s,t}$).[9] The subscript s indexes the number of up to N different programs (or groups of programs) in question.[10]

By using first differences estimation, we eliminate unobserved time-invariant firm fixed effects that may drive firm-specific productivity growth effects. In the longer run, this may turn out to be a strict assumption. If firms enter an innovation support program that initiates a new firm specific growth trend, then we are dealing with time-varying firm effects. However, in the short event windows that we measure impact, we do not consider this to be a likely source of inconsistency.

We effectively measure annual productivity growth rates over two years for all firms that received support in any given year from 2002 to 2009 and compare them with non-participating firms.

FIGURE 4.1 illustrates the principle of measuring participation. Participation can happen in any year, but we only include an observation if a firm has no participation activity before nor after the observation year – in this case the observation year is 2005. From 2003 to 2005 neither firm participates. In 2005 some firms participate and some do not. We effectively compare firm productivity growth rates between 2005 and 2007, taking into account a range of other sources of productivity growth. Thus we can isolate the potential participation effect.

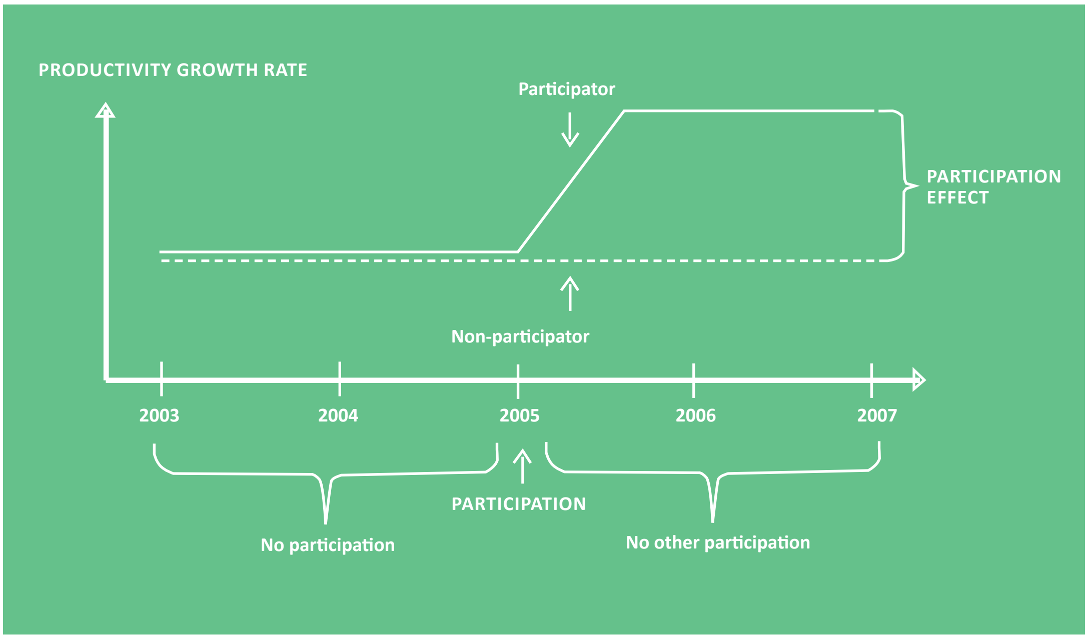
What happens after two years? We do not know. Will the firm remain on a higher productivity growth path? Intuitively that seems unlikely that entering a program suddenly transforms how a firm runs its business in any situation. We find it reasonable to assume that a firm temporarily grows faster than it would have and that the observed increased productivity growth rate is a combination of the normal, underlying growth rate and a one-time increase in productivity.

9 We do not consider dynamic additive effects between programs, e.g. that firms join one program in 2003 and another program in 2007. We showed in section 3, that very few firms are represented multiple times, across time, in our sample.

10 We also measure the overall impact of participating in any program. In this case we have just one indicator variable, $participation_{i,s,t}$, and the following estimating equation:

Figure 4.1

Assessment of impact on firm productivity growth from participating in a program



Notes: The figure shows the narrowing of the full sample of firms to comprise only relevant firms under stricter criteria.

Selection

A concern when performing impact assessment of programs that are designed to spur innovation and R&D activities is that the firms receiving support irrespective of participation or not have the potential to innovate and increase productivity growth, or plainly grow at a faster pace. One descriptive fact is that firms that innovate tend to employ more intensively highly educated workers (see CEBR 2013b). Our inclusion of the share of highly educated workers at the time program participation is initiated can account for this possible confounding effect. The inclusion of this information accounts for trend differences stemming from unleashed productivity potential of a highly educated workforce in participating firms that initially deliver relatively low productivity levels.[11]

However, participating firms could already be growing at a faster pace than non-participants. Clearly we must address this issue.

One way is to specify a lagged dependent variable model by adding lagged productivity to equation (3). This gives us the following fixed effect specification of a lagged dependent variable model (LDP) as an alternative to equation (4):

$$\Delta y_{i,t} = \alpha + \theta \Delta y_{i,t-2} + \beta_1 \Delta k_{i,t} + \beta_2 \Delta l_{i,t} + \beta_3 education_{i,t} \sum_{s=1}^{N} \gamma_s participation_{i,s,t} + \delta_j + \eta_t + \Delta \varepsilon_{i,t} \qquad (5)$$

We estimate the above equation using pooled OLS.

If the decision to participate in a program at time t is correlated with growth in productivity leading up to time t, $\Delta y_{i,t-2}$, then leaving out $\Delta y_{i,t-2}$ (as in equation 4) will bias the estimated coefficient of participation, γ_s. If $\theta<0$, the estimate will be biased downward if we leave out $\Delta y_{i,t-2}$, and if $\theta>0$, the

11 The underlying motivation for assuming productivity potential from highly educated workers comes from numerous correlation studies that document the relationship estimate will be biased upwards if we leave out $\Delta y_{i,t-2}$,. Note that, in general, we do not need $\Delta y_{i,t-2}$ but only $\Delta y_{i,t-1}$ (i.e. a one period difference from t-1 to t). We use two periods because 1) it is more stable to use annualized growth rate over two periods, and 2) we are looking back two periods anyway to observe prior participation activity.

The fixed effects specification of the LDP model suffers from $\Delta y_{i,t-2}$ and $\Delta \varepsilon_{i,t}$ being correlated by construction, making the OLS estimator never fully consistent.

Instead of accounting for the omitted variable bias using a fixed effects LDP model we can use a two-stage least squares (2SLS) approach, instrumenting lagged productivity growth with further lags of the productivity level.[12] This instrumental variable (IV) approach will account for selection of firms that were already growing at faster pace before participating in a program.

As we described in section 3, the estimation samples only include participating and non-participating firms that did neither receive support two years before the starting year of the observed difference or during the two subsequent years we observe firm performance.

Thus, using a clean sample of participation activity, accounting for lagged productivity growth both using the LDP approach and performing an IV estimation taking into account historical productivity growth, delivers a sound foundation for estimating participation effects.

In the next section we present the results of performing the simple pooled OLS fixed effects estimation not account for historical growth (equation 4), pooled OLS fixed effects estimation of the LDP model (equation 5), and the 2SLS IV approach.

__12__ Anderson & Hsiao (1981) suggested the idea of using productivity levels lagged two periods as an instrument for productivity growth lagged one period. See Verbeek (2008) for a discussion of the method and alternative specifications. See also Nickell (1981) and Angrist & Pischke (2009). Griffith, Redding & Van Reenen (2004) argue to use IV approach for robustness if TFP measurement error is a concern.

5 Results

In this section we present the results from applying the methods we discussed in section 4. We present results based on *Estimation Sample 1* (firms with less than 500 employees) in section 5.1, while presenting results of alternative specifications for robustness checks in section 5.2.

We present the resulting estimates starting with the overall average effect of participation without distinguishing between the programs. From that general average estimate of contact with the support system, we search for individual participation effects of the 16 programs. However, we do have a sufficient number of observations for all programs to conclude upon, which is why we finally supplement with estimated participation effects based on groups of programs.

All estimations are carried out on a panel dataset of firms that received support within the period 2002-2009. We estimate participation effects with and without controlling for *historical productivity growth*, defined as the annualized growth rate in the two years leading up to participation. In order to avoid estimates contaminated by time-overlapping support, we effectively rule out observations from firms that also received support two years before or after observed participation. All these criteria are described in detail in section 3.

In section 5.1 we present the main results, and elaborate further in section 5.3, commenting on circumstances and how they relate to other papers and reports that have measured effects of individual programs. In section 5.2 we test the robustness of the estimates using alternative samples and adding more control variables.

5.1
Main results

A few general comments about all estimations in this section can be made: The models exhibit significant coefficients with an adjusted R2 of about 0.3. A high R2 with insignificant variables would be an indicator of multicollinearity issues among the explanatory variables and possibly with omitted variables. Multicollinearity inflates standard errors of explanatory variables and causes wide range of insignificant estimates. Thus, even if we, beforehand, checked the cross-correlations between the explanatory variables, we might mistakenly conclude that missing effects were the result of reality, but in fact influenced by multicollinearity with omitted variables

- Firms in contact with the support system increased productivity growth by 2.5-2.9 percentage points, on average, following program participation.

TABLE 5.1 presents the results of simply estimating whether firms that entered any program subsequently had higher productivity growth than firms that did not have contact with the support system.

Column (1) shows the results of a pooled OLS estimation, where we do not take lagged productivity growth into account when estimating the effect of participation on subsequent productivity growth. The results suggest that participating firms on average grew 2.5 percentage points faster per year over two years following project initialization. Not controlling for former performance, however, unquestionably introduces a potential bias that we must account for.

When we account for historical productivity growth (a lag dependent OLS specification), defined as growth in the two years leading up to project initialization, we observe that serial correlation exists for the dependent variable in the estimation. The estimates suggest that participating firms grew 2.9 percentage points faster that non-participants. One concern in the literature when dealing with TFP measurement is measurement error. If measurement error is a risk, the OLS estimates in column (2) could be biased. One approach to correct this problem is to instrument historical growth. The results are shown in column (3). Using this approach, we observe that the participation effect is similar to the simple OLS estimate in column (1). However, we can then not conclude that the specification in column (1) is correct. We can conclude only on columns (2) and (3).

We also observe that the concern for not controlling for the share of high skilled workers is not, relatively speaking, a primary bias concern in this case. However, while it contributes to productivity with highly significant estimates, an estimated coefficient of 0.01 suggests that at the starting point for performance measurement, a firm with 10 percentage points higher skill share compared to another firm predicts 0.1 percentage points higher annual productivity.

The estimates in TABLE 5.1 are very generalizing, because participation covers 16 programs, some of which are very different programs. In TABLE 5.2 we present the resulting estimates from measuring participation effects from each of the 16 different programs.

- The detailed participation effects obtained from individual programs show evidence of variation ranging from no significant difference with non-participants to 4.1 percentage points higher productivity growth rates.

We described, earlier in section 3, that we do not have enough observations to conclude on some of the programs, and in general we only have a reasonable number of observed participations on a few programs. These programs include *Innovation Agents* (252), *Innovation Consortia* (91), *Innovation Networks* (327), *Innovation Voucher*, and *Innovation Assistant* (167). These programs and also Industrial PhD (51) and Open Funds (32) are presented in TABLE 5.2. The rest are left out of the tables as we have even fewer observations, however, they are included in the estimation.

As in TABLE 5.1, we refrain from concluding on the results from the model in column (1) that

Table 5.1

Average effect on annualized productivity growth from participation in any program

	1 OLS	2 OLS (LDP)	3 IV
Participation	0.0246*** (0.00720)	0.0293*** (0.00678)	0.0247*** (0.00718)
High skill share	0.0100*** (0.00327)	0.0134*** (0.00315)	0.0101*** (0.00326)
Historical productivity growth		-0.211*** (0.00277)	-0.00505 (0.00514)
Observations	350,429	350,429	350,429
Unique firms	87,719	87,719	87,719
Participations	1,140	1,140	1,140
Adjusted R2	0.284	0.332	0.286

Notes: All estimations are based on (first difference) fixed effects estimations and include controls for time variation and industry trends (NACE3) (see section 4.1). The dependent variable is firm valued added growth (log points) controlling for (log point) labor and capital growth (i.e. a proxy for productivity growth). Effects cover program participation observed from 2002 to 2009. Only firms that did not receive support two years before and after observed participation/non-participation are included. Historical productivity growth refers to twoyear lagged productivity growth. ***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively.
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

does not take into account historical productivity growth. The results on *Industrial PhD* and *Innovation Agents* do not indicate any effects. Firms participating in *Innovation Consortia* are significant at the 10 percent level in the LDP specification but (borderline) insignificant in the IV specification, suggesting a weak tendency to higher average growth rates of 4.1 to 2.7 percentage points.

While observations on *Industrial PhD* and *Innovation Consortia* are somewhat few in numbers to firmly conclude on, we have enough observations to conclude that firms associated with *Innovation Agents* do not, on average, subsequently grow faster than firms not associated with participation. The estimated coefficient is close to zero and insignificant.

Innovation Networks, *Innovation Voucher*, and *Innovation Assistant* show evidence of participation effects.

Significant at the 1 and 5 percent level (LDP and IV respectively), the estimates of 4.0 and 3.6 percentage points for *Innovation Networks* clearly indicate that firms participating in *Innovation Networks* subsequently grow at a faster pace than other firms.

Firms active within the *Innovation Voucher* program show effects of around 3.5 percentage points at the 10 percent significance level. Firms that made use of the *Innovation Assistant* program to hire their first highly educated workers significantly (1 percent level) increased productivity up to 4.1 percent faster annually than other firms, according to the LPD specification. Using the IV specification, borderline significant at the 5 percent level, the average estimated effect was a little lower, 2.9 percentage points.

Table 5.2

Effect on annualized productivity growth from participation in a specific program

	1 OLS	2 OLS (LDP)	3 IV
Industrial PhD	-0.0127 (0.0394)	0.00173 (0.0361)	-0.0124 (0.0392)
Innovation Agents	-0.00273 (0.0144)	-0.000977 (0.0129)	-0.00269 (0.0144)
Innovation Consortia	0.0271 (0.0182)	0.0405* (0.0219)	0.0274 (0.0182)
Innovation Networks	0.0360** (0.0141)	0.0397*** (0.0134)	0.0361** (0.0140)
Innovation Voucher	0.0357* (0.0205)	0.0343* (0.0177)	0.0356* (0.0204)
Innovation Assistant	0.0289* (0.0150)	0.0407*** (0.0142)	0.0292* (0.0149)
Open funds	0.0348 (0.0246)	0.0380* (0.0224)	0.0349 (0.0245)
High skill share	0.0100*** (0.00327)	0.0134*** (0.00315)	0.0101*** (0.00326)
Historical productivity growth		-0.211*** (0.00277)	-0.00505 (0.00514)
Observations	350,429	350,429	350,429
Unique firms	87,719	87,719	87,719
Participations	1,140	1,140	1,140
Adjusted *R2*	0.284	0.332	0.286

Notes: All estimations are based on (first difference) fixed effects estimations and include controls for time variation and industry trends (NACE3) (see section 4.1). The dependent variable is firm valued added growth (log points) controlling for (log point) labor and capital growth (i.e. a proxy for productivity growth). Effects cover program participation observed from 2002 to 2009. Only firms that did not receive support two years before and after observed participation/non-participation are included. Historical productivity growth refers to twoyear lagged productivity growth ***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively. For presentation reasons, the table presents only programs with a minimum of 32 observations (Open funds). "Industrial PhD" (51) and "Innovation Consortia" (91) also have less than 100 observations (see TABLE 3.2).

Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

The final program estimate that we have not commented on is the Open funds program. Here we find rather weak evidence of growth effects. Whether this is a correct finding or not, regarding both the level and missing significance is unclear, as 32 observations are too few to conclude upon. If we want to somehow conclude indirectly on a program such as Open Funds, we must group the program with other similar programs.

As discussed earlier the programs can be grouped into broader categories of program types. In TABLE 5.3, we present results from grouping the individual programs. As in the previous table, we present only results for groups with a reasonably sufficient amount of observations. Of the four groups presented, *Industrial PhD, and Innovation Assistant* remain ungrouped. The two other groups are *Collaboration and Counseling and Support*.

- Grouping individual programs documents statistically significant and positive subsequent productivity growth for the three program groups Collaboration, Counseling and Support, and Skill enhancing employment (i.e. Innovation Assistant).

The resulting estimates from grouping the programs are influenced by the underlying individual program estimates presented earlier. 96 percent of the observations in *Collaboration* cover *Innovation Consortia*, *Innovation Voucher*, and *Open Funds*, all with positive individual coefficient estimates of 2.7-4 percentage points.

For *Counseling and Support*, however, 98 percent of the observations cover *Innovation Networks* (56 percent) and Innovation Agents (43 percent) with very different estimates (see TABLE 5.2). Therefore, not surprisingly, *Collaboration* programs come out with a higher average estimate of participation effects compared to *Counseling and Support* programs. With effectively so few individual programs behind the average estimate we find it hard to argue that Collaboration projects in general are more fruitful than *Counseling and Support* projects. We leave that discussion up to the reader.

5.2 Robustness

In this section we briefly present results from adding more control variables, and results

Table 5.3

Average effect on annualized productivity growth from participation in a program type

	1 OLS	2 OLS (LDP)	3 IV
Collaboration	0.0375** (0.0147)	0.0371*** (0.0137)	0.0375** (0.0147)
Counseling and support	0.0198* (0.0101)	0.0237** (0.00950)	0.0199** (0.0101)
Industrial PhD	-0.0130 (0.0394)	0.00170 (0.0361)	-0.0127 (0.0392)
Skill enhancing employment	0.0282* (0.0149)	0.0399*** (0.0142)	0.0285* (0.0149)
High skill share	0.0100*** (0.00327)	0.0135*** (0.00315)	0.0101*** (0.00326)
Historical productivity growth		-0.211*** (0.00277)	-0.00507 (0.00514)
Observations	350,429	350,429	350,429
Unique firms	87,719	87,719	87,719
Participations	1,140	1,140	1,140
Adjusted *R2*	0.284	0.332	0.286

Notes: All estimations are based on (first difference) fixed effects estimations and include controls for time variation and industry trends (NACE3) (see section 4.1). The dependent variable is firm valued added growth (log points) controlling for (log point) labor and capital growth (i.e. a proxy for productivity growth). Effects cover program participation observed from 2002 to 2009. Only firms that did not receive support two years before and after observed participation/non-participation are included. Historical productivity growth refers to two-year lagged productivity growth. ***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively. For presentation reasons, the table presents only groups with a minimum of 50 observations (see TABLE 3.2). "Collaboration" covers both national and international collaboration (see TABLE 3.2).
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

using *Estimation Sample* 2 that is identical with Estimation Sample 1 except for covering only firms with less than 100 employees.

Adding size control to the main estimations

We have already argued why we use the specified models (i.e. LDP and IV models with fixed effects). Thus, we are confident in using these models to measure productivity effects. For the main estimation results we have included central variables that influence firm trend productivity growth. Only one of these is a level variable specific to the firm. Thus, one can argue that firm trend growth may be heterogeneously influenced at the firm level: Large firms may increase productivity at a slower pace than smaller low-productive firms catching up, or large firms may increase productivity faster because they are well-established and ready to embrace new technology or knowledge. Thus, we add level variables indicating firm size before observed productivity growth (i.e. at year t before observing productivity growth from year t to year t+2).

TABLE 5.4 shows the results of adding labor stock (columns 1 and 4) and revenue (column 2 and 5), separately and jointly (columns 3 and 6), to account for the possibility that historical productivity growth does not capture trends of firms of certain size in terms of number of employees or revenue. Columns 1 and 2 show the results of adding labor stock and revenue separately for the LDP model specification, while columns 3 and 4 show the results of adding labor stock and revenue separately for the IV model specification.

Recall that we are already controlling for industry effects. Thus, when controlling for any size effects that may be attributed industry (and also other controls), firm size in terms of revenue is associated with below average subsequent productivity growth (-0.8 to -0.4 percentage points). Labor stock, on the other hand, is positively associated with subsequent productivity growth (0.6 to 1.1 percentage points).

Table 5.4

Robustness: adding more control variables to the LDP and IV models

	1 OLS (LDP)	2 OLS (LDP)	3 OLS (LDP)	4 IV	5 IV	6 IV
Industrial PhD	-0.0195 (0.0362)	0.00986 (0.0361)	-0.0105 (0.0362)	-0.0284 (0.0403)	0.00880 (0.0379)	-0.0141 (0.0388)
Innovation Agents	-0.00753 (0.0128)	0.00157 (0.0129)	-0.00520 (0.0127)	-0.0069 (0.0149)	0.00278 (0.0137)	-0.0043 (0.0139)
Innovation Consortia	0.0270 (0.0225)	0.0469** (0.0218)	0.0457** (0.0226)	0.0161 (0.0184)	0.0448** (0.0189)	0.0427** (0.0193)
Innovation Networks	0.0278** (0.0135)	0.0447*** (0.0134)	0.0368*** (0.0132)	0.0283** (0.0144)	0.0470*** (0.0137)	0.0390*** (0.0137)
Innovation Voucher	0.0260 (0.0179)	0.0377** (0.0177)	0.0306* (0.0175)	0.0312 (0.0213)	0.0415** (0.0191)	0.0349* (0.0196)
Innovation Assistant	0.0358** (0.0142)	0.0424*** (0.0142)	0.0352** (0.0140)	0.0232 (0.0154)	0.0370** (0.0144)	0.0270* (0.0145)
Open funds	0.0222 (0.0227)	0.0445** (0.0225)	0.0312 (0.0245)	0.0249 (0.0257)	0.0483** (0.0236)	0.0349 (0.0267)
Labor stock (log)	0.0111*** (0.0004)		0.0525*** (0.0009)	0.0064*** (0.00042)		0.0583*** (0.00093)
Revenue (log)		-0.0044*** (0.00041)	-0.0461*** (0.0009)		-0.0083*** (0.0004)	-0.060*** (0.001)
High skill share	0.0159*** (0.0031)	0.0136*** (0.0032)	0.0262*** (0.0031)	0.0106*** (0.0033)	0.0116*** (0.00320)	0.0250*** (0.0032)
Historical productivity growth	-0.213*** (0.0028)	-0.209*** (0.0028)	-0.202*** (0.0027)	0.0496*** (0.0032)	-0.0828*** (0.0027)	-0.031*** (0.0026)
Observations	350,429	350,380	350,380	350,429	350,380	350,380
Participators	1,140	1,140	1,140	1,140	1,140	1,140
Adjusted *R2*	0.334	0.332	0.344	0.259	0.316	0.313

Notes: The table shows re-specifications of columns (2) and (3) in TABLE 5.2. For technical notes, consult the notes in TABLE 5.2.***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively.
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

We see that the two added controls affect the estimates and standard errors differently, and they affect different programs differently:

- Conclusions on the estimates for *Industrial PhD* and *Innovation Agents* remain unchanged.
- Estimates for *Innovation Consortia* turn insignificant and become smaller when controlling for labor stock (column 1 and 4), but turn significant at the 5 percent level and larger when controlling for revenue instead (Column 2 and 5).When adding both controls simultaneously the estimates are significant at the 5 percent level and higher than the main results estimates.
- Estimates for *Innovation Networks* are robust to adding controls though the size of the estimates change somewhat
- Estimates for *Innovation Assistant* changes are not notably affected by the joint adding of the two controls.
- Conclusions on *Open Funds* (few observations) are unchanged, as estimates are not considerably influenced, and standard errors tend to become somewhat larger.

Some concerns when adding further controls are that these controls introduced are correlated with other control variables (e.g. if size is largely determined by industry), and that using the first difference method to eliminate fixed effects also removes variation in the first place. Thus, it can be hard to argue why some estimates turn insignificant. Is it caused by better controls or lost variation? The overall impression, though, is that adding the controls proves robustness of the estimation strategy, because the main results, in general, are confirmed. In some cases the estimates (e.g. Innovation Consortia) increase more than the standard errors are inflated, thus turning more significant. It is tempting to conclude, that the added controls result in a more well specified model. However, we stick to our initial specification, because we argue from a well-known theoretical setup, where we have not modeled size heterogeneity.

Results for smaller firms

Now we focus on estimations using *Estimation Sample 2*, i.e. the sample that uses the same criteria as *Estimation Sample 1*, except for limiting the analysis to firms with less than 100 employees.

TABLE 5.5

Robustness: average effect on productivity growth from participation in any program - firms with less than 100 employees

	1 OLS (LDP)	2 OLS (LDP)	3 OLS (LDP)
Participation	0.0266*** (0.00819)	0.0323*** (0.00767)	0.0266*** (0.00820)
High skill share	0.00950*** (0.00330)	0.0131*** (0.00317)	0.00949*** (0.00329)
Historical productivity growth		-0.211*** (0.00277)	0.000825 (0.00500)
Observations	342,255	342,255	342,255
Unique firms	86,510	86,510	86,510
Participations	942	942	942
Adjusted *R2*	0.282	0.330	0.281

Notes: All estimations are based on (first difference) fixed effects estimations and include controls for time variation and industry trends (NACE3) (see section 4.1). The dependent variable is firm valued added growth (log points) controlling for (log point) labor and capital growth (i.e. a proxy for productivity growth). Effects cover program participation observed from 2002 to 2009. Only firms that did not receive support two years before and after observed participation/non-participation are included. Historical productivity growth refers to two-year lagged productivity growth. ***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively.
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

Although limiting the analysis in the first place to firms with less than 500 employees removes the concern of inherent differences between small firms and very large firms, we still have to address the concern that the firm size band is still too large, and that relatively small initiatives cannot be interpreted as firm productivity growth improvements. The *Innovation Assistant* program, for example, supports firms with less than 100 employees, but in the main analysis, we compare these firms with firms that have more than 100 employees. A criticism to the analysis can be therefore that, despite adding size controls in the robustness check, we are comparing with firms that never could apply or take advantage of this program. Limiting the analysis to firms with less than 100 employees addresses such an issue for this particular program.

For some programs, the number of observations drops in relatively large numbers. For others, the number remains relatively large. The overall number of observed participations drops from 1,140 to 942. Thus, we keep 82 percent of the observations from *Estimation Sample 1*, while *Industrial PhD* falls from 59 to 31, *Innovation Consortia* from 91 to 59, and *Open Funds* from 32 to 24. The rest of the programs presented earlier are still relatively well-represented compared to *Estimation Sample 1* (firms with less than 500 employees): *Innovation Assistant* (unaffected, program criteria), *Innovation Voucher* and *Innovation Agents* (93 percent), and *Innovation Networks* (81 percent).

TABLE 5.5 presents the average participation estimate from having contact with the innovation and research support system. The results show, that the estimates increase slightly from a span of 2.5-2.9 percentage points extra productivity growth to 2.7-3.2 percentage points.

TABLE 5.6

Robustness: effect on productivity growth from participation in a specific program - firms with less than 100 employees

	1 OLS	2 OLS (LDP)	3 IV
Industrial PhD	-0.0409 (0.0614)	-0.0184 (0.0562)	-0.0410 (0.0614)
Innovation Agents	-0.00381 (0.0153)	-0.00293 (0.0136)	-0.00382 (0.0153)
Innovation Consortia	0.0268 (0.0252)	0.0518* (0.0311)	0.0267 (0.0252)
Innovation Networks	0.0406** (0.0168)	0.0449*** (0.0159)	0.0406** (0.0168)
Innovation Voucher	0.0413* (0.0218)	0.0396** (0.0189)	0.0413* (0.0218)
Innovation Assistant	0.0294* (0.0152)	0.0415*** (0.0144)	0.0294* (0.0152)
Open funds	0.0399 (0.0299)	0.0438 (0.0269)	0.0398 (0.0299)
High skill share	0.00953*** (0.00330)	0.0131*** (0.00317)	0.00952*** (0.00329)
Historical productivity growth		-0.211*** (0.00277)	0.000842 (0.00500)
Observations	342,255	342,255	342,255
Unique firms	86,510	86,510	86,510
Participators	942	942	942
Adjusted *R2*	0.282	0.330	0.281

Notes: The table follows the setup in TABLE 5.2.***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively.
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

Turning to the individual programs, in TABLE 5.6, we see that inference made from *Innovation Consortia, Innovation Networks, Innovation Voucher*, and *Innovation Assistant* remain unchanged. Some estimates have increased by a minor factor of about 1/10.

Finally, we add revenue and labor stock as size controls in TABLE 5.7, (presenting only the results on joint inclusion of the variables, which can be compared with columns 3 and 6 in TABLE 5.4).

From TABLE 5.7 we note that the estimate for *Innovation Consortia* turns significant at the 10 percent level.

Changing the control group to firms with less than 100 employees has no effect on the *Innovation Assistant* estimate. Adding size controls lowers the LDP estimate, but the IV estimate hardly changes, both compared to the main results in TABLE 5.2 (firms with less than 500 employees) and the results in TABLE 5.6 (equivalent estimations for firms with less than 100 employees).

Table 5.7

Robustness: effect on productivity growth from participation in a specific program - firms with less than 100 employees and further controls added

	OLS (LDP)	IV
Industrial PhD	-0.0335 (0.0560)	-0.0470 (0.0598)
Innovation Agents	-0.00736 (0.0135)	-0.00542 (0.0147)
Innovation Consortia	0.0603* (0.0322)	0.0458* (0.0272)
Innovation Networks	0.0422*** (0.0155)	0.0431*** (0.0162)
Innovation Voucher	0.0361* (0.0187)	0.0413** (0.0208)
Innovation Assistant	0.0355** (0.0141)	0.0280* (0.0147)
Open funds	0.0365 (0.0298)	0.0386 (0.0329)
Labor stock (log)	0.0533*** (0.000905)	0.0588*** (0.000948)
Revenue (log)	-0.0469*** (0.000935)	-0.0571*** (0.00100)
High skill share	0.0256*** (0.00314)	0.0240*** (0.00321)
Historical productivity growth	-0.201*** (0.00273)	-0.0317*** (0.00260)
Observations	342,255	342,255
Unique firms	86,510	86,510
Participators	942	942
Adjusted *R2*	0.342	0.311

Notes: The table shows re-specifications of columns (2) and (3) in TABLE 5.2 using Estimation Sample 2 (less than 100 firms). For technical information, consult the notes in TABLE 5.2. ***, **, and * refer to statistical significance at 1, 5, and 10 percent level, respectively.
Source: CEBR calculations using Statistics Denmark registry data and DASTI's Innovation Danmark database.

5.3 Discussion

Our point of reference is that firms make decisions and initiate projects that potentially enhance their performance and probability of survival, and we know that firms use incentives for employees in order to perform better. Search for innovative business solutions (from process innovation to marketing innovation), and research into better or new products include possible actions for investing in future firm performance.

Public research and innovation support programs aim to support firms with external knowledge from specialists (e.g. *Innovation Voucher*) or connect researchers and firms via research networks *(e.g. Innovation Consortia*). Other programs aiming to increase firm skills, involve skill upgrading (*Innovation Assistant). The Industrial PhD* program potentially combines skill upgrading with collaboration between industry and research institutions.

If all of the above mentioned activities can be associated with company strategies that we expect can increase firm performance, we are able to measure potential effects. Performance can be measured in many ways, but one objective measure of firm performance is productivity improvement. We measure *productivity growth enhancing effects*, i.e. we measure whether firm total factor productivity of participating firms subsequently grow faster than non-participating firms, while taking into account historical productivity growth performance.

Some challenges exist in effect measurement at the firm level. First of all, are observed support activity a minor spin-off of other firm projects? If this is the case we are not measuring firm performance related, first and foremost, to program grants. We cannot infer from the data if this is the case. However, by ruling out participation activity in preceding and subsequent years, we can at least say that we observe only firms that are actively participating that one year in a four year period. If participation activity for some firms is a by-product of other primary initiatives that firms would have initiated regardless of support options, we can expect to see them repeatedly in the data. These firm observations are thus not included in our sample.

No effect, why?
For some programs in section 5.1 (main results) we do not find any effects. The question arises, why? The general answer is that we cannot say why, but we can list some possible explanations:

Explanation 1:
There is no effect of the initiatives associated with the program in question.

Explanation 2:
We measure effects on firms that exist two years after participation. Some firms may close down due to financial restraints or bankruptcy. (Successful) firms may also have been bought up. However, a program may still have had a positive, or negative, impact that we will never be able to measure.

Explanation 3:
Data availability complicates impact assessment.

Explanation 4:
Firm productivity growth is not a suitable measure for all programs.

Explanation 1 is plain and simple. To take *Innovations Agents* as an example, we find no enhanced productivity growth following participation. The finding that *Innovation Agents* participation does not return differential growth is not surprising, but rather comforting. The *Innovation Agents* program is designed to give firms a “checkup” and then forward them to relevant private consulting or to other programs such as *Innovation Voucher*. One possible conclusion is that *Innovation Agents* check up on Danish firms

13 See Chai & Shih (2013) for an impact assessment of DNATF, although it considers other performance measures than productivity growth.

exhibiting productivity growth rates that are not different from that of the typical non-participating firm.

Explanation 2 tells us that we can only measure effect on survivors and firms that remain independent. Some programs in particular may in practice engage participation by firms that are more likely to be bought up than other firms. What effects would be in these firms, we cannot infer, as is the case for firms closing down or restructuring into a new firm.

Explanation 3 covers the Mother of all data analysis problems. One of the initiatives, that we cannot measure an effect for, concerns projects under *Danish National Advanced Technology Foundation* (*DNATF*). When imposing our criteria we end up with just 11 observations. However, as evident in the robustness results, there is apparently a tendency to find effects for smaller firms (i.e. estimates are larger for most programs when analyzing on firms with less than 100 employees, compared to analyzing on firms with less than 500 employees). Thus, one could imagine that the effect of larger scale research projects dominate impact on performance, compared to other programs such as the innovation voucher, that typically awards DKK 100.000-500.000 for knowledge assistance at a recognized knowledge institution. Thus, it might be reasonable to allow for other minor participation activities when evaluating the impact of, for example, *DNATF* projects.[13]

Another clear issue is that measuring performance of projects, two years into a research project, lasting up to five years, is a strict and possibly unrealistic criterion. Even if we could measure performance for a longer term, we might never observe the productivity effects. If a firm, for example, is bought before its new innovative products or business methods start generating revenue, the productivity effects generated are hidden in the value of the firm. Furthermore, the longer the observation period, the more likely it will be that other projects or circumstances influence the performance measure.

Explanation 4 suggests that certain programs could practically target firms that are relatively productive and well-established. These firms may be past revolutionary productivity changes. For these firms, steadily increasing, or just maintaining, productivity may be the realistic short run target. If this argument is correct, the research support system may be an endogenous part of an already integrated private-public (or private-private) research collaboration environment. Furthermore, using other performance measures may reveal that highly productive firms expand following participation. CEBR (2011b) finds that firm workforce of firms hiring *Industrial PhD's* (partially supported) grow faster following the decision and action to hire *Industrial PhD's*.

A program such as the Industrial PhD hosts the potential to increase macro-level productivity, because the program allows talented industrial researchers to obtain a PhD while working in the industry, bringing with them fundamental research knowledge from academic institutions. Thus, one can imagine that such a flexible option in the statutory educational system can facilitate labor shifting from low-productive firms to high-productive firms, improving macro level productivity because talented researchers instead work and contribute to firm value added more efficiently. Such macro level productivity effects would never show up in a micro level study such as ours.

Comparison to other impact evaluations

In this section we compare some of our estimates to previous reports and articles that have tried to measure the impact of a particular program or initiative on productivity. We focus on the programs that we have highlighted in section 5.1 (main results), because these are the programs where we have enough observations to, at least, make careful inference.
Comparing estimates and methods directly

14 DASTI (2011) investigates effects of private-public research interaction.

is difficult, because the underlying data approaches are, in general, different from ours. We also use a different productivity measure, which we also point out below. This project is the first project to take all other known innovation and research support programs into account, ruling out simultaneous or short run overlapping participation effects.

We cannot conclude on *Danish Council for Strategic Research* projects and *DNATF* projects. An impact assessment of *DNATF* has been completed by Chai and Shih (2013) focusing not on productivity growth but on other measures such a patent activity (a likely indicator of future value creation), firm survival, and employment growth.

Another study of research activities includes DASTI & DAMVAD (2013), which, among other things, estimates production functions with R&D capital inputs. The study finds, across firms, a significant and increasing productivity level for firms that have built up more R&D capital stock.[14]

We find that *Industrial PhD* is not associated with significantly higher productivity growth following participation. This finding is consistent with CEBR (2011b). Though (TFP) productivity growth is not higher for participants, as in this study, CEBR (2011b) also investigates individual wages and proposes that the higher wages found for PhD candidates suggests high individual productivity. Furthermore, as we have noted earlier, productivity potential may be hidden in long product introduction time paths. One potential indication of this is patent seeking activity, and CEBR (2011b) does find that employing *Industrial PhD's* is associated with subsequent increased patent activity.

We do not find solid proof of effects of productivity gains for *Innovation Consortia*. However, adding size controls, the estimate increases and turns significant. Kaiser and Kuhn (2012) and CEBR (2010) have also evaluated productivity but using labor productivity instead of TFP. They find no effects on labor productivity. We cannot directly compare these two results, because the productivity measures are different. Using labor productivity does not account for changes in capital use. The TFP-growth estimation takes account of this. Thus, our results suggest that accounting for capital changes in productivity effects matters.

The *Innovation Assistant* program has been evaluated by CEBR (2013a). In a detailed study Kuhn follows workers wage histories and firm performance, finding no effect on labor productivity. As we explained above, we cannot directly compare results from Kuhn with our results, because we use a different setup that measures TFP growth.

6 Conclusion

The innovation and research support system includes programs that are associated with enhanced (possibly only short run) productivity growth of 2.5 percentage points annually the first two years following participation.

We find that (all effects are measured by annualized added growth measured in percentage points):

- Following participation in *Innovation Network* (with an effect of 3.6 percentage points), *Innovation Voucher* (3.6), and *Innovation Assistant* (2.9) participating firms grow faster than non-participating firms.[15]

- When limiting the analysis to firms with less than 100 employees and accounting for heterogeneous productivity growth trends depending on firm size, the effects are amplified and become more firmly significant.

- For firms with less than 100 employees participation in *Innovation Consortia* is associated with enhanced growth performance (4.6).

- Firms participating in *Industrial PhD*, *Innovation Agents*, or *Open Funds* do not grow significantly faster than other similar firms. The result for *Industrial PhD*, though based on somewhat few observations, is in line with previous studies. *Open Funds*, though positive, is insignificant, but based on just 32 observations.

In our analysis we control for past productivity growth performance and exclude other observations of firms with other participation activity in the years preceding and following the observation of participation, adding a particular feature to our sampled firms. These criteria allow us not to worry about contaminated program effects from other programs and that we are not picking up that firms that participate simply grew faster in the first place.

The identification of program participation effects relies on the assumption that we can fully attribute the knowledge transferred via these programs to firm performance. We set up an analytical framework that allows causal inference on productivity growth performance following participation. However, we currently have no possibilities of revealing, or accounting for, whether particular types of firm innovative or knowledge enhancing activities would have generated the same result had the programs not existed, and that firm contact with the support system is simply correlated with these particular firm activities. We rely on the assumption that firms seeking support initiate activities based on grants and benefit first and foremost from having established contact with the support system.

The performance measure in this report is productivity growth enhancing effects. We recommend that our conclusions are used under the recognition that we do not consider other, possibly more likely, performance measures that may induce macro level productivity effects. Programs can help highly productive firms to expand. Such help to high-productive firms can improve macro level productivity (by shifting workers from

15 *All effects are annualized added growth measured in percentage points.*

lower productive jobs in low-productive firms) but those productivity effects would never show up in our type of micro level study of firm productivity growth. We encourage further program comparison studies such as this study into other performance measures.

Some programs suffer from few observations, partly because we impose the aforementioned criteria. These programs include *The Danish Council for Strategic Research, EUopSTART, Eurostars, FP7, Research Voucher, Gazelle* Growth, The Danish National Advanced Technology Foundation, Innovation Incubators, and SPIR.

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About the project

This project was prepared for The Danish Agency for Science, Technology and Innovation (DASTI) under The Ministry of Higher Education and Science.

The scope of the project was to conduct the first comprehensive productivity impact assessment of the Danish system of innovation and support system. This is the first time that effect studies include comprehensive information about many programs, ruling out latent connected effects of other programs.

To assure quality we consulted two highly qualified professors, Professor Søren Bo Nielsen and Associate Professor Battista Severgnini, who possess vast knowledge within the fields of public policy on science, research and innovation, and empirical productivity studies. We thank them for helpful and constructive comments. The authors, alone bear the responsibility of the entity of report.

About CEBR

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Economic Impact of Business investments in R&D in the Nordic Countries

- A microeconomic analysis

Ministry of Higher Education
and Science
—
Danish Agency for Science,
Technology and Innovation

Economic Impacts of Business Investments in R&D in the Nordic Countries - a Microeconomic Analysis

By

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Research, development and innovation have become increasingly important areas of policy. As such, knowledge about the impact of R&D investments in the business sector has become an increasingly important focal point of policymaking. According to endogenous growth theory (Romer 1994), growth is a result of endogenous forces such as new knowledge and technology. R&D plays a significant role in both creating new knowledge and technology. Furthermore, international economic research points out that an important share of the economic growth in advanced economies comes from public and business sector investments in R&D and innovation.[1] Moreover, both the OECD and recent academic research point out, that the return on investment from R&D is significant.

The purpose of this study is to analyse differences and similarities of the economic impacts of business R&D investments of companies, based on the same harmonised methods and data across four Nordic countries. The study provides the reader with new knowledge about the effects of investments in private R&D. The knowledge will have implications for policy makers' ability to assess and measure the performance and successes of national research and innovation systems.

Only a few international studies compare productivity effects of R&D investments of companies across advanced industries and countries.[2] A better understanding of the differences in companies' R&D investment patterns across industries and across countries will enhance policy making. In this regard, a comparative econometric analysis across advanced economies is useful. In cooperation with the Nordic Council of Ministers, the Danish Agency for Science, Technology and Innovation has taken initiative to compare and analyse the private business investments in research and development (R&D) and the effects of these investments in four Nordic countries.

The data collected for the econometric analysis includes the countries Denmark, Norway, Sweden and Finland, and covers the years 1999-2010. The analysis has been carried out by the Danish Agency for Science, Technology and Innovation and DAMVAD consulting with support from a task group with participants from the relevant agencies from Norway, Sweden and Finland, The Danish Productivity Commission and the Secretariat for the Nordic Council of Ministers, Nordforsk and Nordic Innovation (NICe).

The study is the first of its kind that applies such an extensive data material. The data makes it possible to analyse and compare the private R&D investments and the effects hereof across several countries, company sizes and sectors. This makes the study the most thorough and extensive international analysis within its field, which, in itself, renders the results interesting. The study has been presented to the OECD and is expected to provide the basis for a series of articles in internationally peer-reviewed journals.

1.1 MAIN RESULTS

This study offers new insights and knowledge to the question; what is the effect of investments in private R&D? The results show that across the four countries, there is a positive return on additional investments in R&D. This implies that in each of the four Nordic countries for the average company an additional euro invested in R&D has a positive net-return. At country level, Danish companies obtain the highest marginal rate of return on R&D capital[3] of 34.2 percent. Finnish and Norwegian companies both obtain a marginal rate of return of 22.7 percent, while Swedish companies obtain a marginal rate of return of 16.4 percent. Though the companies have experienced one of the worst economic crises in history, they are still able to generate a strong rate on return on their R&D investments. Table 1.1 shows the results.

Table 1.1 – The marginal rate of return on private R&D capital

COUNTRY	RATE OF RETURN
Denmark	34.2 %
Norway	22.7 %
Finland	22.7 %
Sweden	16.4 %

Note: The rate of return is given by: $\rho = \gamma \cdot \frac{Y}{R_{t-1}} - \delta$, Where y is R&D elasticity, $\frac{Y}{R_{t-1}}$ is the median of value added to R&D capital (lagged one year) ratio, and δ is the depreciation rate set to 15 per cent which is the typical rate used in the literature. The R&D elasticity, R, is derived from the augmented Cobb-Douglas function $Y_{i,t} = Ae^{\lambda t} C^{\alpha}_{i,t-1} L^{\beta}_{i,t} R^{\gamma}_{i,t-1} X^{\sigma}_{i,t-1} e^{\varepsilon}$

Across the four Nordic countries, some sectors yield higher returns from their R&D capital. Whereas Finland is strong in turning R&D into value within the manufacturing sector (both high tech as well as medium and low tech industry), the Swedish information and communications technology (ICT) sector has a high marginal return of R&D capital. In Denmark and Norway, it is particularly the knowledge intensive business service (KIBS) sector.

[1] Parham (2010).

[2] See Chapter 2, table 2.1.

[3] "We base R&D capital on accumulated values of R&D activities conducted within the companies. We use a depreciation rate of 15 per cent, which is in line with most literature, see Graversen and Mark (2005)."

On the other hand, we show that the ICT sector in Finland and the manufacturing sector in Sweden are not generating profit from additional R&D capital building. Section 1.2 and Chapter 4 further elaborates on these results.

The development in R&D investments differs in the four Nordic countries. In Denmark we see that the R&D intensive industry constitute a growing share of the total private R&D. The "top-5" R&D-intensive industry increased their share of total private R&D from 55 percent in 2005 to 69 percent in 2010. This implies that some industry to a large extent exploit R&D and might not need public funding directly to increase their R&D. On the other hand the "non top-5" industry struggle to keep up their R&D level. These industry will potentially benefit the most from public R&D programmes.

Norway is notoriously falling behind when it comes to the level of R&D. This has been described in OECD as the Norwegian paradox.[4] The lacking behind is caused by a low level of investment among larger companies with more than 250 employees. Whereas this group of companies encounter 72 percent (3.4 billion euros) of private R&D in Denmark, 81 percent in Sweden (6.0 billion euros) and around 81 percent in Finland (3.9 billion euros), the share is only 35 percent in Norway (0.8 billion euros).

In Sweden, the traditional manufacturing sector is bleeding. The level of R&D-investments drops from 3.3 billion euros to 2.7 billion euros. This influences the overall level of R&D-investments in Sweden that has decreased with an annual 2.9 percent a year from 2005 to 2009. This is just the opposite in the other countries where the R&D-investments have increased between 2.7 and 4.7 percent a year from 2005 to 2010. The consequence of falling investments in the manufacturing sector is distinctly shown in the rate of return of R&D capital in the sector. The return rates are much lower than in the other Nordic countries.

Half the R&D investments in Finland are concentrated in one industry, the electronics industry. This implies a risk for Finland and their top ranking in the Innovation Union Scoreboard and other innovation rankings. If something dramatic happens to Nokia which is driving most of the R&D in this industry there is a strong risk that the R&D of this particular company stagnates or even decreases. Furthermore, all subcontractors who innovates and do R&D as a response to the demand from Nokia will be at risk. We are yet to see the consequence of the sale of Nokia, but it will without doubt affect the R&D spending in Finland.

1.2 THE EFFECT[5] OF INCREASED INVESTMENT IN PRIVATE R&D

This study confirms the findings of the scientific literature that there is a positive relationship between R&D investments in the business sector and labour productivity. In all the Nordic countries, there is a statistically positive and significant impact of business R&D on labour productivity. There are, however, some variations between countries. Furthermore, not only differences between countries, but also variations across business sectors and across different types of companies are present. The Danish companies yield the highest rate of return with 34.2 percent. Finnish and Norwegian companies yield 22.7 percent in rate of return on their R&D capital whereas Sweden yields 16.4 percent.

The rate of return differs when focusing on different sectors. Table 1.2 shows the differences in the rate of return by sector. Finnish companies in the manufacturing sector are good at turning their R&D into increased value added compared to the other Nordic countries. On the other hand Swedish companies within the ICT sector and the Danish and Norwegian companies within the knowledge intensive business sector are good at creating value added from their R&D.

Smaller companies experience a rate of return on their R&D that is smaller than the rate of return in larger companies. Table 1.3 shows that the rate of return of R&D is increasing with company size. It is only in Sweden where this does not seem to be the case.

Table 1.2 - The marginal rate of return of business R&D investments by sector

	SECTOR					
Country	High tech industry	Medium and low tech Industry	ICT	Business service	Other service	Other sectors
Denmark	11.0%	19.6%	9.6%	56.6%	65.4%	Insg.
Norway	9.5%	15.3%	5.8%	34.6%	109.1%	49.8%
Finland	18.8%	26.3%	1.8%	13.3%	6.0%	60.4%
Sweden	3.5%	-1.2%	24.9%	10.2%	3.1%	108.3%

4 OECD (2007) Economic Survey: Norway, Paris: OECD

5 The effect is measured as the rate of return of a median company in all the divisions. Yet calculating the rate of return is the same as stated in the note of Table 1.1:"The rate of return is given by: $\rho = \gamma \cdot \frac{Y}{R_{t-1}} - \delta$, Where y is R&D elasticity, $\frac{Y}{R_{t-1}}$ is the median of value added to R&D capital (lagged one year) ratio, and δ is the depreciation rate set to 15 per cent which is the typical rate used in the literature. The R&D elasticity, R, is derived from the augmented Cobb-Douglas function $Y_{i,t} = Ae^{\lambda t} C^{\alpha}_{i,t-1} L^{\beta}_{i,t} R^{\gamma}_{i,t-1} X^{\sigma}_{i,t-1} e^{\varepsilon}$

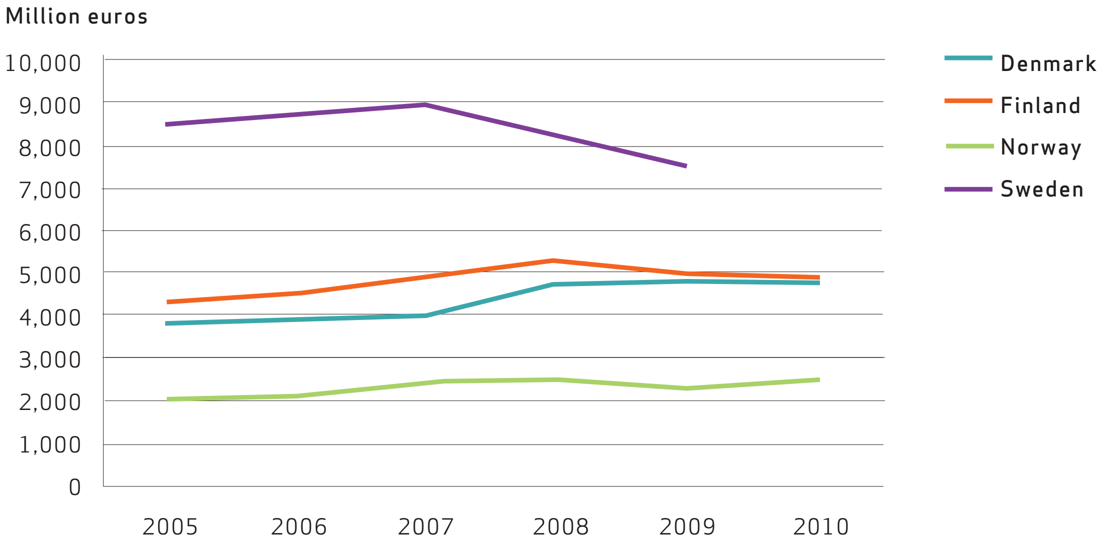
Table 1.3 - The marginal rate of return of business R&D investments by company size

COMPANY SIZE				
Country	2-49 employees	50-99 employees	100-250 employees	More than 250 employees
Denmark	12.4 %	15.0 %	37.4 %	63.7 %
Norway	9.4 %	22.8 %	31.3 %	125.3 %
Finland	10.2 %	17.9 %	23.1 %	51.5 %
Sweden	4.9 %	-4.4 %	-7.6 %	24.6 %

1.3 OVERALL BUSINESS R&D INVESTMENTS IN THE NORDIC COUNTRIES

When measured as a share of GDP, Finland and Sweden invest the most in R&D among the Nordic countries. However, the gap between Denmark and Sweden and Denmark and Finland has been reduced significantly. In 2010 Denmark invested about five billion euros in private R&D, which was comparable to the level of Finland measured in absolute investments. Sweden invested about 7,5 billion euros in 2009 and Norway invested about 2,5 billion euros in 2010, see Figure 1.1

Figure 1.1 - Business R&D investments, 2005-2010



Note: Data for Sweden is only available in uneven years. Data in even years are interpolated (an average on the two nearby years). Fixed 2010-prices.

Norway notoriously falls behind the other Nordic countries when it comes to R&D-investments. This is known as the Norwegian paradox and is surprising because the share of companies with research investments is the same for Norway and the other Nordic countries. In particular, the paradox is due to the lack of R&D-investments among the large companies in Norway compared to Denmark, Finland and Sweden. As table 1.4 shows only 35.3 percent of the private R&D in Norway stems from companies with more than 250 employees. The corresponding percentages in the other countries are 72.1 in Denmark, 80.7 in Finland and 81 percent in Sweden.

Table 1.4 – Business R&D investments as percentage of total R&D in 2010 company size

COMPANY SIZE	DENMARK	NORWAY	FINLAND	SWEDEN
2-49 employees	16.6 %	32.8 %	9.9 %	7.0 %
50-99 employees	5.5 %	12.2 %	4.1 %	4.2 %
100-250 employees	5.8 %	19.7 %	5.3 %	7.8 %
More than 250 employees	72.1 %	35.3 %	80.7 %	81.0 %

Note: Data for Sweden is only available in odd years. 2010 data is not available. 2009 data used instead.

In Finland, half of the private R&D-investments are concentrated in the electronics industry, which is dominated by Nokia. This trend is not recognizable in the other Nordic countries, where R&D-investments are more evenly distributed across different industries. In Denmark it is the Pharmaceutical industry, in Norway it is the ICT services and in Sweden we see that the industries of Electronics, Research and Development and Pharmaceutical are leading R&D-investment industries. Table 1.5 shows the top-5 industries in 2010.

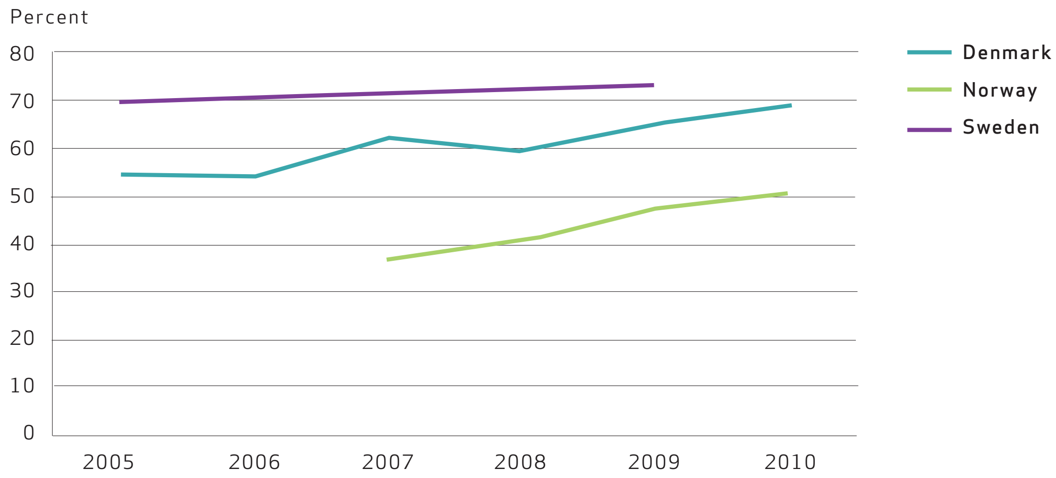
Table 1.5 -Top five industries with largest R&D investments in percent of total business R&D investments in 2010

RANKING	DENMARK		FINLAND		NORWAY		SWEDEN	
1	Pharmaceuticals	20%	Electronics	53%	IT and information services	14%	Pharmaceuticals, Research and development (R&D), Electronics and Oil refineries*	47 %
2	IT and information services	13%	Mechanical engineering	7%	Consultancy and advisory services	12%	Transport and transportation equipment	19%
3	Mechanical engineering	13%	IT and information services	6%	Publishing. TV and radio	9%	Real estate activities	7%
4	Research and development (R&D)	12%	Manufacturing of electrical equipment	5%	Food. drink and tobacco	9%	Mechanical engineering	7%
5	Financial and insurance activities	11%	Consultancy and advisory services	3%	Electronics	6%	IT and information services	4%

Note: 2010 data from Denmark, Finland and Norway and 2009 data from Sweden.
*In Sweden the industries *Electronics, Research and development (R&D), Pharmaceuticals and Oil refineries* are not included individually do to discretion because a single large company dominates the whole industry. Sweden does not collect statistics on R&D investments in the industry *Financial and insurance activities*.

The most research heavy industries in Denmark, Norway and Sweden make up for an increasing share of the total private R&D investments, see Figure 1.2. From 2005 to 2010 the top-5 R&D-industries increased their share of total R&D. This implies that despite the economic crisis the most R&D investing industries continues to expand their R&D activities. On the other hand, it also implies that less R&D intensive industries are falling behind and struggle to maintain the level of R&D. These industries might be those of most interest of the R&D and innovation policy and programmes.

Figure 1.2 - Development in 2010 top five industries' R&D investment as a percentage of total business R&D investment in Denmark, Norway and Sweden from 2005 to 2010.



Note: Due to limited data access, it has not been possible to produce the graph for Finland.
Note: There is a shift in industry classification in Norway in 2007, which has not fully been accounted for in "Electronics". Therefore the top five industries in Norway is not shown before 2007.

1.4 ANALYTICAL FRAMEWORK AND DATA IN THE STUDY

There is an extensive scientific literature of how R&D investments affect company output. Traditionally, the theoretical framework is based on a Cobb-Douglas function; see Hall et al. (2009), Bjørner & Mackenhauer (2011) and Hall & Mairesse (1995). In this study we have followed this tradition. We have assumed that the production function for companies can be approximated by the following augmented Cobb-Douglas function in the four inputs; physical capital C, labour L, R&D or knowledge capital R and export intensity X:

Equation 1 - Augmented Cobb-Douglas function

$$Y_{i,t} = Ae^{\lambda t}\, C_{i,t-1}^{\alpha}\; L_{i,t}^{\beta}\, R_{i,t-1}^{\gamma} X_{i,t-1}^{\sigma} e^{\varepsilon}$$

According to the augmented Cobb-Douglas function the company's output Y or value added[6] is determined by the four inputs. As a first step in analysing the microeconomic impacts of business R&D investments in the Nordic countries a baseline model, which is derived from the augmented Cobb-Douglas function, is estimated for each country.[7]

Equation 2 - Baseline model

$$\ln\left(\frac{Y_{i,t}}{FTE_{i,t}}\right) = a_B + \lambda_t + \alpha \ln\left(\frac{C_{i,t-1}}{FTE_{i,t}}\right) + \beta \ln\left(FTE_{i,t}\right) +$$

$$\gamma \ln\left(\frac{R_{i,t-1}}{FTE_{i,t}}\right) + \sigma \ln\left(X_{i,t-1}\right) + \varepsilon_{i,t}$$

For further information about the methods we refer the reader to Chapter 2 and 3.

1.4.1 DATA

The analysis is built on extensive use of micro level data. Data consist of both company level data and individual data. The data covers:

- Research and development statistics every year from the year 1999 to 2010 in Denmark, Finland and Norway. In Sweden the statistics are only collect every second year, thus the data covers every second year from 1999 to 2009.
- The national statistics based on the European Community Innovation Survey. The survey is conducted every second year in Finland, Norway and Sweden and every year in Denmark. The results cover every second year from 2006 to 2010 in Finland, Norway and Sweden and every year in Denmark from 2006 to 2010.
- Further we use business statistics on company level from 2004 to 2010 in all countries.
- Finally we add educational and wage on the employees in the companies we analyse. Data covers individuals from the year 2005 to 2010.

The results are based upon models exploiting panel data. The panel is built on the research and development statistics. Large companies are included in the R&D statistics each year while small and medium-sized companies are represented by taking a random sample. This results in an 'unbalanced' panel. For some companies, there are data for all years, while others are represented only one or a few years. Missing observations will be imputed when it is reasonable. For imputation rules and more information about the more than 20,000 observation see Chapter 3.2.

6 Value added is a measure of output, and is defined as revenue – non-labour costs of inputs. Value added is comparable across countries and economic institutions.

7 See section 3.1.2 The production function for a detailed overview of the derivation of the baseline model.

2. IMPACT AND EFFICIENCY OF R&D AND INNOVATION IN THE PRIVATE SECTOR: HOW DO WE MEASURE THE EFFECTIVENESS OF THE R&D AND INNOVATION SYSTEM?

2.1 INTRODUCTION AND MOTIVATION

Knowledge about the impact of R&D investments in the business sector has become increasingly important for policy making. International economic research points out that an important share of the economic growth in advanced economies comes from public and business sector investments in R&D and innovation.[8] The OECD as well as recent academic research point out, that the return on investment from R&D is significant.[9] However, despite the vast and increasing amount of empirical analysis connecting investments in R&D with the performance of a company there is still a need for new knowledge. We lack knowledge about patterns, explanations and differences in the rates of return and in the level of commercial exploitation of business R&D across comparable countries.

There are only a few international studies which compare productivity effects of R&D investments of companies across advanced economies.[10] Knowledge on the differences in the rate of return across different types of business investment, industries and various countries is important for policy makers as well as for investors and businesses in order to determine whether the economic effects of a country's or company's R&D investments are sufficient or not.

In order to understand the differences in business R&D investment patterns we have conducted a comparative econometric analysis. The analysis works across sectors and in Denmark, Finland, Norway and Sweden and determines the impact of investments on labour productivity of investments in private R&D.

The purpose of this study is to describe the development of R&D investments in companies in Denmark, Finland, Sweden and Norway and to analyse impact patterns, differences and similarities based on harmonized methods and data across the four countries.

2.2 LACK OF ECONOMIC IMPACT EVIDENCE IN SCOREBOARDS AND RANKINGS

The innovation system in Denmark, Finland, Norway and Sweden works well when the system is measured against the key innovation indicators of the OECD and the Innovation Union Scoreboard of the European Commission. Finland, Sweden and Denmark are in the scoreboard pointed out as being among the five innovation leaders in Europe.

Denmark, Finland and Sweden are also among the countries in the world with the highest share of investments in R&D in relation to their gross national products (GDP). The public sectors in these three countries invests more than one percent of GDP in R&D and the companies invest each year between two and three percent of GDP in research and development activities.

Finally, the Competitiveness Reports of the European Union focus on the relationship between input indicators such as investments in public and private businesses and output indicators such as patent applications and scientific publications instead of impact indicators such as employment, productivity and economic growth. This makes it difficult to measure the impact on the competitiveness of investments in research and development. It also makes it difficult to evaluate the efficiency of research and technology developments in the private sector.

International analyses show that there is a significant positive return on investments in R&D. However, methods and indicators on how to measure the rate of return vary across countries. Therefore, it is difficult to obtain an accurate and analytically based picture of the rate of return of business R&D investment and even more difficult to obtain any credible picture of the differences in return on R&D investments across sectors, types of companies and countries. Because of these difficulties and lack of broadly accepted analytical evidence, there is a risk that organisations, observers and politicians jump to conclusions on the ability of businesses to turn R&D into value creation and economic growth.

Most international analytical studies are based on non-econometric analyses and non-economic indicators. In the Competitiveness Reports of the European Union the conclusions on efficiency of research and innovation investments are estimated based on various non-economic indicators and without the use of proper econometric statistical methods.

Furthermore, there is no evidence of statistical relationships between the analysed indicators and economic indicators such as GDP growth, employment, labour productivity, total factor productivity etc.

2.3 EVIDENCE FROM THE LITERATURE - EMPIRICAL STUDIES OF BUSINESS R&D

Some national studies and national innovation strategies such as the strategies of the United Kingdom and Australia state that more than fifty percent of GDP growth stems from investments in innovation, development of new technologies and research. An American study shows that a significant part of the growth in GDP since the Second World War comes from developments of new technologies.[11]

In a recent Danish study from 2010[12] the societal impact of increased private R&D is estimated. If private R&D increases by 0.4 percent of GDP the effects on society will correspond to a 1.75 percent increase in GDP over a five year period. The same study estimates that an increase in business R&D capital by one percent increases labour productivity by 0.125 percent.

8 Goel et al. (2008).
9 The Danish Agency for Science, Technology and Innovation (2010)
10 Hall et al. (2009) and Griliches and Mairesse (1990).
11 Goel et al. 2008
12 The Danish Agency for Science, Technology and Innovation (2010)

The latter estimate is confirmed by several articles in the international economic literature where the return on companies R&D investment in developed economies are estimated positive, but vary across studies.

In order to put these results into a broader context, Table 2.1 below provides an overview of the results from other analyses for comparison.

Table 2.1 - Overview of empirical studies of R&D and productivity

STUDY	R&D ELASTICITY	R&D RATE OF RETURN	POPULATION
Minasian (1969)	0.11-0.26		17 US companies; 1948 to 1957
Griliches (1980a)	0.03 – 0.07		39 US manufacturing companies; 1959 to 1977
Schankerman (1981)	0.10 – 0.16		110 US companies (Chemical and petroleum); 1963 cross-section
Griliches and Mairesse (1984)	0.19	35% *	77 US companies (in research intensive sectors); 1966 to 1977 133 US companies; 1966 to 1977
Cuneo and Mairesse (1984)	0.20	-90% *	182 French companies; 1972 to 1977
Griliches (1986) Sample 1 Sample 2	0.12-0.17 0.09	51% to 76% *	491 US companies; 1972 cross section 1977 cross section
Englander, Evenson, and Hanazaki (1988)	-0.16 – 0.50		16 industries in 6 countries; 1970 to 1983
Mansfield (1988)	0.42		17 Japanese companies
Griliches and Mairesse (1990) Sample 1 Sample 2	0.25 – 0.41 0.20 – 0.56		525 US companies; 1973 to 1980 406 Japanese companies; 1973 to 1980
Hall and Mairesse (1995)	0.05 – 0.25 0.00 – 0.07	78% *	197 French firms; 1980 - 1987, cross-sectional estimation. Time series-estimation
Smith et al. (1999)	0.08-0.13		110 Danish companies investing in R&D activities; 1987 to 1995
Wang and Tsai (2003)	0.19	8% to 35% *	136 Taiwanese manufacturing companies; 1994 to 2000
Graversen and Mark (2005)	0.02-0.11		662 Danish companies investing in R&D acitivities; 1991-2001
Foray et al. (2009)	0.096	23% *	1,513 US companies; 2004-2006
Ortega-Argilés et al. (2009)	0.10	35%	532 EU companies; 2000-2005
Danish Agency for Science, Technology and Innovation (2010)	0.05-0.199	66%	20,000 Danish manufacturing and service companies investing in R&D activities; 1997 to 2007
Bjørner & Mackenhauer (2011)	0.12-0.14		1,029 Danish companies investing in R&D activities and R&D activities within; 1999 to 2007

Source: Chapter 19, *Congressional Budget Office 2005, Graversen and Mark (2005)* and *Hall and Mairesse (1995)* and "*Productivity effects of business research, development and Innovation*" Danish Agency for Science, Technology and Innovation (2010).
** computed using means or medians of the variables.*

Many of the results in Table 2.1 are not comparable. This is due to various differences in population and methodology. Some use panel data whereas others deploy cross section analysis. The populations are also very different. From less than 20 companies and up to more than 20,000 companies, and covering different industries. The strength of this study is that it allows for comparing estimation results across country and industry.

2.4 WHICH QUESTIONS ARE ADDRESSED IN THE STUDY?

Many questions remain unanswered when searching through the literature on business R&D investments. Is the impact of R&D investments in the business sector higher or lower in France, the United States, and Denmark than in other developed economies like Japan, Finland, Norway and Sweden? Are companies in some countries better than companies in other countries in transforming investments in R&D and new technologies into productivity growth and growth in gross profits of the business sector? Furthermore, are companies in certain sectors better in transforming investments into productivity growth than companies in other sectors?

In order to answer these and similar questions, this study analyses microeconomic data from Denmark, Finland, Norway and Sweden and conducts an econometric analysis based on common economic indicators and harmonized research-based analytical methods.

Denmark, Finland, Norway and Sweden all have adopted the guidelines of the Frascati manual on collecting R&D data. Furthermore, the four countries have adopted the Community Innovation Surveys (CIS) as a part of their R&D statistic. Information about R&D and innovation activities are thus gathered using the same guidelines in all of the countries and are directly comparable.

The unique data allows us to address the following questions:

- What is the effect of business R&D investment on the companies' labour productivity across countries, sectors and company size?
- Which countries, sectors and companies have the highest return of business R&D investments among the Nordic countries?
- What is the return on investments in green technologies compared to the return on investments in welfare technologies or other type of technologies?
- What are the similarities and differences with respect to R&D investments across the Nordic countries, across industries or across various sizes of companies?
- Is the level of R&D investment in companies too low?

2.5 CONTRIBUTORS TO THE STUDY

The Danish Agency for Science Technology and Innovation (DASTI) is the driver of this Nordic study in close collaboration with the Nordic Council of Ministers and relevant partners in Finland, Iceland, Norway and Sweden.

A special thanks to Raine Hermans from Tekes, Finland, Kirstin Oxley and Svein Olav Nås from Research Council of Norway, Norway, Carl Jacobsson from The Swedish Research Council, Sweden, Pouline Terpager Rasmussen and Daniel Holmberg from Nordic Council of Ministeries, Sóley Morhens and Leif Eriksson from NordForsk, Natalia Glette from Nordic Innovation, Peter Sonne-Holm from the Danish Productivity Commission, Denmark and Fredrik Melander from The Danish Ministry of Higher Education and Science, Denmark .

DAMVAD Consulting has run the Nordic study and conducted the analysis. Thomas Alslev Christensen (chairman of the Nordic study), Hanne Frosch and David Boysen-Jensen from DASTI and Michael Mark and Asbjørn Boye Knudsen from DAMVAD Consulting have written the report. Any misinterpretations and other inconsistencies are solely the responsibility of the authors.

2.6 STRUCTURE AND NOVELTY OF THE STUDY

Firstly, the methodology and the data of the study is presented and discussed. The econometric analysis is based on micro data from all the statistical offices in the four small advanced Nordic countries. This enables the use of internationally recognized academic methods to perform econometric analysis on the effects of R&D in companies. This is presented in Chapter 3.

Secondly, a broad return on business investment analysis has been conducted. It is the first time the R&D elasticities and the marginal rates of return of companies R&D investment across the Nordic countries have been systematically analysed and documented in the same project with the same methods across business sectors and industries as well as small advanced economies. This is presented in Chapter 4.

Thirdly, the analysis estimates the impact of R&D investments in green technologies and welfare technologies in all four Nordic countries. This is presented in Chapter 4.

Finally, we do a benchmark analysis of the business R&D investments and innovation. The benchmark compare R&D-activities, innovation and the impact of innovation across various industries and size of businesses in the Nordic countries. As such, the analysis generates a rare comparison between the Nordic countries, which take account of the differences in the business structure, industries and technologies in each of the analysed countries. This is presented in Chapter 5 and Appendix A and B.

This chapter describes the methods and data applied to analyse the microeconomic returns of business R&D investments in the Nordic countries. The analyses and the results will follow in Chapter 4.

The methods applied to analyse the marginal return of private R&D investments are based on international literature. The literature points out that there is a wide range of challenges in analysing the relationship between private R&D investments and productivity. The approach is based on economic theory and applies well tested empirical models. This is important both for statistical accuracy and for interpretation of the results.

3.1 METHODOLOGY

The following section reviews the econometric and statistical methods applied to analyse the return of business R&D investments in the Nordic countries. The methods used in this analysis are based on well-known best practice in the economics literature; see a comprehensive international review by Hall et al. (2009), and the two Danish studies; Danish Agency for Science, Technology and Innovation (2010) and Bjørner & Mackenhauer (2011).

3.1.1 R&D CAPITAL AS A MEASURE OF R&D INVESTMENTS

Knowledge assets are intangible and therefore difficult to measure. This is a challenge when measuring the effects of R&D. It is not only business investments in R&D or innovation in the present year that are assumed to affect productivity, but also investments conducted in the past. The present discounted value of past R&D investments accumulates to R&D capital in the same way as companies' physical capital. The accumulated R&D capital is calculated based on the perpetual inventory method; see Hall et al. (2009):

$$R_{it} = (1-\delta)R_{i,t-1} + IR_{it},$$

where R_{it} is the R&D capital stock in period t. $R_{i,t-1}$ is the value of the accumulated past R&D investments. IR_{it} is the new R&D investment in period t and δ is the depreciation rate of R&D capital. The depreciating rate of R&D investments is set to 15 percent each year, which is the typical rate used in the scientific literature. Alternative depreciation rates have been tested in the scientific literature with only minor differences in the results; see Hall et al. (2009), and Graversen & Mark (2005). The scientific research studies show that different depreciation rates do not affect the size of the return of R&D investments.

Calculating the level of R&D capital is based on the perpetual inventory method. The method implies that R&D capital is based on the level the first year where we have an observation and the assumption that the company in the years before had a constant real growth in research investments corresponding to g (assumed to be 5 percent):

$$R_{i,99} = \frac{IR_{i,99}}{g+\delta}$$

An important aspect in this business R&D investment analysis is that the explanatory variable is based on the accumulated investments (R&D capital) and not just the R&D investment of the year in question. This way, an R&D investment continues to have effect in the years after the investment is made. It is important to emphasize that the calculated return of investments does not relate directly to private R&D investment, but to the accumulated R&D capital.

We do not include R&D bought by the companies. This analysis focuses on the return on building knowledge capacity. When companies buy R&D, a large part of the knowledge capacity building takes place outside of company and thus the capacity building is different in nature from when the R&D activities are conducted within the company. Further there is a risk of double counting if the R&D is bought from another company and we cannot distinguish between different sources from whom the companies buy their R&D. Finally bought R&D is not available in all the included countries.

3.1.2 THE PRODUCTION FUNCTION

There is an extensive scientific literature of how R&D investments affect company output. Traditionally, the theoretical framework is based on a Cobb-Douglas function, see Hall et al. (2009), Bjørner & Mackenhauer (2011) and Hall & Mairesse (1995). We follow this tradition from the scientific literature and assume that the production function for companies can be approximated by the following augmented Cobb-Douglas function in the four inputs; physical capital C, labour L, R&D or knowledge capital R and export intensity X[13]:

$$\ln\left(\frac{Y_{i,t}}{FTE_{i,t}}\right) = \alpha_B + \lambda_t + \alpha \ln\left(\frac{C_{i,t-1}}{FTE_{i,t}}\right) + \beta \ln\left(FTE_{i,t}\right) + \gamma \ln\left(\frac{R_{i,t-1}}{FTE_{i,t}}\right) + \sigma \ln\left(X_{i,t-1}\right) + \varepsilon_{i,t}$$

According to the Cobb-Douglas function the company's output Y or value added[14] is determined by the four inputs.

The model is then estimated after the usual log-transformation converting it into a linear model:

13 Export intensity = Export / Revenue

14 Value added is a measure of output, and is defined as Value added = value of production – Intermediate consumption. Value added is comparable across countries and economic institutions.

$$\ln(Y_{it}) = a_B + \lambda_t + \alpha \ln(C_{i,t-1}) + \beta \ln(L_{i,t}) +$$
$$\gamma \ln(R_{i,t-1}) + \sigma \ln(X_{i,t-1}) + \varepsilon_{i,t}$$

The coefficients measure the elasticity of value added with respect to physical capital, labour and R&D and export intensity, thus describing the marginal effect of the inputs on the output variable.

The empirical model (henceforth the baseline model) applied to analyse the marginal return to business R&D investments in the Nordic countries in Chapter 4 becomes:

$$\ln\left(\frac{Y_{i,t}}{FTE_{i,t}}\right) = a_B + \lambda_t + \alpha \ln\left(\frac{C_{i,t-1}}{FTE_{i,t}}\right) + \beta \ln(FTE_{i,t}) +$$
$$\gamma \ln\left(\frac{R_{i,t-1}}{FTE_{i,t}}\right) + \sigma \ln(X_{i,t-1}) + \varepsilon_{i,t}$$

Where $\boldsymbol{aB}$ and λt are dummy variables meant to capture any sector and time specific effects, respectively. The baseline model explains company i's labour productivity in year t as function of company i's current labour force (FTE) and the physical capital, R&D capital and export intensity from the previous year t-1.

It is essential to distinguish between stock and flow variables. The focal point of this analysis is the coefficient to the R&D capital stock (y), i.e. the accumulation of past R&D investments which is not to be confused with the present level of R&D investments, a flow variable. The estimated coefficient of R&D capital (y) is in this functional form interpreted as the elasticity of R&D capital. This elasticity is interpreted as the percentage increase in value added per employee when R&D capital increases by one percent. A positive elasticity of R&D capital means that an increase in R&D capital will increase the value added per employee.

3.1.3 CONTROLLING FOR DOUBLE COUNTING AND THE QUALITY OF LABOUR

It is important to note the potential double counting of R&D employees and employees in general. Both of these are encountered by the labour variable, L_t, and indirectly by the R&D capital, R_{t-1} in the production function stated above. The labour cost for R&D employees are contained in the R&D investments (and thereby in R&D capital) and consequently R&D employees will be counted in both variables. Double counting with respect to R&D related capital investments in both R&D capital and physical capital exists because R&D is not treated as an investment in accounting. It is important to correct for double counting in order to avoid a downward bias in the effect of R&D capital on productivity, see Hall et al. (2009) and Bjørner & Mackenhauer (2011).

Due to lack of data, it has not been possible to correct for all cases of double counting. However, by far the largest component of R&D investments is the cost to R&D personnel. Capital investments represent a relatively small share of R&D investment and correspondingly R&D expenses are very small relative to the value added. Thus, the data has been adjusted for double counting of R&D staff which is the main component. This is done by subtracting the number of R&D employees in full time equivalents (FTE) from the total number of employees (FTE).

Furthermore, it is important to adjust for the quality of labour in the calculation of return on R&D investments. Companies with a high level of R&D can also have many highly educated employees. If not taken into account, there will be a tendency for the return on R&D investments to be overestimated because highly educated tend to be more productive, see Hall et al (2009).

The correction with respect to the quality of labour can be based on the method used by the Bjørner & Mackenhauer (2011), where employees with different levels of education are weighted in relation to the average wage for the education category on the assumption that different average wages reflect differences in productivity (quality of labour). Labour is weighted up to unskilled workers (i.e. an employee with a long education weighs more than an unskilled worker).

Due to data limitation concerning wage data, it has not been possible to create a comparable quality adjusted labour index across Sweden, Norway, Finland and Denmark. To get comparable results we have chosen not to apply the quality adjusted labour index in the analysis (see Appendix C.2 for the labour force quality corrected baseline model and corresponding weights). The consequence is that the return on investments will be slightly overestimated in all four countries. However, we have no reason to believe that the overestimation will differ significantly between the four countries. Sweden, Norway, Finland and Denmark all have quite similar labour markets and a comparable wage distribution.

3.1.4 TIME LAGS

There will typically be a time lag between the initial R&D investment and the potential effect on company productivity. The time lag will vary depending on the type of R&D investment involved. Moreover, it is difficult to isolate the effects of R&D investments on a specific time from the effects of accumulated knowledge through previous R&D investments.

The time perspective is analysed from several angles. Firstly, the use of R&D capital (accumulation of past investment in R&D) partially taking into account the time lag in the effect of R&D investments. Secondly, we analyse how R&D capital affects productivity (value added per. employee) with three different time lags respectively; one year, two years and three years.

Using a time lag of two or three years instead of one year only reduces the elasticity of R&D capital with respectively 0.0003 and 0.0006 for Denmark. The same tendency applies for the other three countries (Norway, Sweden and Finland). The estimates are extremely robust concerning different time lags, which is reassuring for the specification of the model and emphasise the strong relation between R&D investments and productivity.

3.1.5 SIMULTANEITY BIAS IN DATA

A condition for the estimation of a productivity model is that the explanatory variables (i.e. labour, physical capital and R&D capital) are exogenous to productivity. This condition is typically not satisfied if the variables are from the same year. Unobserved factors that affect productivity will generally also affect labour, capital and R&D. This can lead to bias in the coefficient estimates (simultaneous bias). One way to reduce this bias is to use input variables from the beginning of the year and productivity at year-end. In the analyses of this study we use R&D capital from the year before and productivity from the actual year to reduce the bias.

An alternative method would have been to use instrument variables, i.e. the regression of input variables on the other explanatory variables that are highly correlated with the input variable, but not correlated with the residuals of productivity. Statistically speaking, this method is preferable, but it has been difficult in practice, given the lack of good instrument variables in the field. It has not been possible to identify any suitable instruments across the Nordic countries and instrumental variable estimation is therefore not applied.

3.1.6 COMPOSITION OF SAMPLE

It is always a question whether or not to include companies without R&D. Generally, analyses estimating the effects of R&D investment on productivity are based exclusively on companies with R&D activities. If companies without R&D activities were to be included in the econometric analysis, it is important to use appropriate methods to address the inclusion of such companies. The methods are relatively complex and require greater analysis of the factors causing companies to invest in R&D or not.[15] Therefore, the analysis conducted in this study focuses exclusively on the R&D performing companies - in line with other similar analyses.

However, it is still important to compare companies with and without R&D investments. For example, productivity per employee varies for companies with and without R&D activities, see Table 3.1. Table 3.1 indicates that R&D active companies are more productive than companies with no R&D activity. It is important to note that R&D is not necessarily the only driver behind higher productivity in Table 3.1; the companies with R&D are typically larger, more capital intensive and have a better educated workforce.

Table 3.1 Productivity ladder

EURO 2010-PRICES	DENMARK	NORWAY	SWEDEN
No innovation	79,945	93,191	64,543
Innovation, no R&D	86,458	116,585	72,642
Innovation & cooporation, no R&D	87,083	114,121	96,566
R&D	124,579	137,053	104,320

Note: *The population only covers companies which are part of the R&D statistic.

15 These methods estimate the propensity to invest in R&D. Furthermore, they estimate what the level of R&D activity would have been, given they had chosen to invest in R&D. The estimated values can later be employed in the productivity analysis. The so-called CDM-model (Crépon et al., 1998) employs a somewhat similar approach to analysing the relationship between innovation and productivity. However, Crépon et al. 1998 estimate the innovation propensity in order to control for selection bias, but only includes R&D active companies.

3.1.7 RETURN ON INVESTMENT

Measuring the return on R&D investments is a subject which has received a great deal of attention in the literature; see Hall et al., 2009 for a comprehensive literature review. Measuring the return on R&D investments is also a focal point of this analysis. More specifically, we are interested in calculating the net return on R&D investment (ρ). The approach to calculating ρ here is to apply the elasticity of R&D capital (γ)[16] :

$$\rho = \gamma \cdot \frac{Y}{R_{t-1}} - \delta$$

where Y/R_{t-1} is the median of the value added to R&D capital (lagged one year) ratio and δ is the depreciation rate set to 15 percent. The depreciation rate is used in order to obtain net returns. Even though alternative depreciation rates only changes the elasticity marginally the choice of depreciation rate is of great importance to the net returns on investments in R&D, henceforth return of investment.

The return of investment gives an estimate of the return at the margin, i.e. given the level of R&D capital stock. A constant elasticity of R&D capital will return different levels of returns of investment for different ratios of value added to R&D capital stock. In fact, returns of investment may even become negative despite a positive elasticity of R&D capital due to the depreciation of existing R&D capital stock. Businesses facing an investment decision should be concerned with the return of investment in R&D and not the just elasticity of R&D capital. An example seems instructive:

Comparing Finland and Denmark; the elasticity of R&D capital in Finland (0.167) is almost twice the size the elasticity of R&D capital in Denmark (0.091). However, a larger elasticity of R&D capital does not necessarily result in a higher level of return on new R&D investments. Since the ratio of value-added to R&D capital stock is much larger in Denmark (the R&D capital intensity is much lower), return on R&D investments ends up being greater in Denmark (34.2 percent) than that of Finland (22.7 percent).

The result in the above example can also be viewed in light of the law of diminishing marginal returns; The median R&D active Danish company has a lower R&D capital intensity compared to the Finnish counterpart. By the law of diminishing marginal returns, the return of R&D in the Danish company will ceteris paribus be greater than for its Finnish counterpart. Of course, this result does not hold in general and depends on the elasticity of R&D capital. A more technical perspective on the result in the above example is that increasing the R&D capital stock is "cheaper" in Denmark than in Finland; the R&D capital stock in Finland is large relative to Denmark, meaning that to increase the R&D capital stock with one percent demands a larger investment in Finland compared to Denmark.

16 Here $\gamma = \rho^b(R_{t-1}/Y)$ with ρ^b being the marginal productivity of R&D capital.

3.1.8 GREEN TECHNOLOGY AND WELFARE TECHNOLOGY SECTORS

It is of special interest to analyse the return of investment of companies that are involved in the production of welfare technology or green technology. Welfare technology and green technology can be categorised as "resource areas". A resource area is an alternative classification of industries compared to the established industry classification; it contains companies across already existing industries. However, resource areas at the industry level are not reported in official registers or databases. Therefore, this project employs a brand new and highly sophisticated method for measuring welfare technology industries and green technology industries. A weight is constructed on the industry level for both types of technology (green and welfare), indicating the level of activity in the production of that particular technology.

Construction of weights is a complex and resource demanding process. The Danish weights for green technology on the industry level are therefore also applied to Norway, Sweden and Finland. The Danish weights for welfare technology on the industry level are applied to Sweden and Finland, but not to Norway; Norway has its own weights calculated. When applying the Danish weights for the other Scandinavian countries it is implicitly assumed that industries that are green in Denmark, say 50 percent green, are also 50 percent green in the other Scandinavian countries.

It is important to note a central reservation regarding the analysis of Green and Welfare technology sectors. We use a weight calculated at industry level and implement the weight on each individual company. As such we assume that all companies have the same weight as the industry. This is a strong assumption and we do not know the full consequence of the assumption. As such the results regarding Green and Welfare technology sectors should be seen as indications rather than exact results.

Green technology sector

The process of statistically defining and delimiting the green technology resource industries is based on different sources. These sources include work done by the OECD and EUROSTAT. The steps described below explain in a sequential way how to define and delimit the industries:

- Technologies, products and services were identified to be either green or non-green based on already accessible information. This identification also involved a discussion with experts on the definition of green technologies, products and services. An example of a green technology is solar power cells.
- Based on the identified green technologies, products and service industries with sales or import of these products are identified through register data.
- The identified industries are equipped with a quantitative weight based on how much of their sales or import that stems from the identified green technologies, products and services.

The data used, consist of the following registers from Statistics Denmark:

- The external trade registers.
- The register of industrial commodity statistics.
- A combined register known as the FIDA.

Furthermore, we used information drawn from the Experian Company Database and information from almost 1,000 homepages of various companies, in order to construct a qualitative weight. They were all assessed and categorised into different levels of green activities. The weights are scaled by the number of employees in each company and accumulated to industry level. Hence, we have a green sector weight between 0 and 1 for 245 industries.

The quantitative and qualitative weight approach has provided us with weights at the 6-digit NACE-code level. Now it is possible to combine the two weights and calculate a common weight for the industries. If the two weights are at the same level, that is, within a range of 20 percentage points, an average of the two is used as the final weight. This was the case for almost 70 percent of the industries. For the remaining industries a manual assessment of the weight difference was performed in order to determine whether to put emphasis on the quantitative weight, the qualitative weight or both of them.

The result is an extensive list of Danish industries all given a weight from 0 to 1 depending on how green each industry is.

Welfare technology sectors

Welfare technology is a general concept that covers several international concepts. This makes it difficult to define and delimit welfare technology. At the same time the boundaries for what welfare technology is and what welfare technology is not are moved, because technologies are developing constantly. Consequently, welfare technology is not definitively defined, but instead different criteria are applied in order to delimit welfare technology. In this mapping of welfare technology companies, welfare technological products and services are delimited using the following guidelines:

- The application of the product or service is crucial; it either needs to be applied in own surroundings or be applied in order to solve an actual need of the target group[16].
- Social gains arising from the application of welfare technological products and services.
- Applying the welfare technology must result in a labour reducing/an optimization element. An example of this is when a greater utility is achieved with the same input of labour.
- Covers both private and public products and services

Guidelines delimiting welfare technology "negatively" include the following:

- Welfare technology products and services do not include medicine or raw materials for production of medicine.
- Activities taking place at the hospital in relation to treatment are welfare technology.

Based on the identification it is possible to construct a weight indicating the level of welfare technological activities. This is calculated as the proportion of welfare technology solutions to total assets of the individual company and can be regarded as a weight indicating the level of welfare technological activities. The procedure for constructing a welfare technology weight follows the same procedures undergone to construct the green technology weight.

The calculations on company level are performed on data from Statistics Denmark (and Statistiske Sentralbyråd for Norway). Since it is not allowed to report the individual company weights, the weights are aggregated to industry level. These quantitative weights are complemented with a qualitative review of a representative subsample of the companies in the industries where we have identified welfare technological activities.

The result is an extensive list of Danish industries all given a weight from 0 to 1 depending on the level of welfare technological activity in the industry.

17 The target group is defined as i) dysfunctional users, e.g. elderly, handicapped or chronically ill individuals ii) permanent or temporary dysfunctional users, iii) the personnel servicing the target group.

3.2 DATA

3.2.1 CONSTRUCTION OF PANEL DATA

The effect of business R&D investment on productivity is a dynamic process which may vary over time. Analyses based on the cross-section of a single year are not capable of analysing the variation over time. This is another argument for estimating the model over time using panel data (cross-sectional data over time).

Large companies are included in the R&D statistics each year while small and medium-sized companies are represented by taking a random sample. This results in an 'unbalanced' panel. For some companies, data is available for all years, while other companies are represented only one or a few years. Missing observations will be imputed when it is appropiate. Thus, the panel data set is constructed as follows:

- Panel data analysis can only be made in companies with at least two observations in the R&D statistics.
- To ensure that the analysis is as representative as possible, all companies with at least two observations are included in the panel to begin with. If there is a gap of minimum four years between two observations, the missing years are not imputed.
- The company will be excluded if it does not have a series consisting of at least two observations with a maximum gap of three years between the observa tions. See the rules for imputation below.
- Very large changes in variables may indicate a merger or division of a company. These changes can have a disproportionate effect on the results. Therefore this analysis follows the methods in Hall and Mairesse (1995) and removes companies with annual growth rates in value added, physical capital, number of employees or R&D capital that is less than -90 percent or greater than 300 per cent.

Imputations rules (see Table 3.2):

1. All companies represented in less than two years are deleted
2. If the last year is missing it is based on the previous year
3. If the first year is missing it is based on the following year
4. If there is missing data from two or three consecutive years the missing data is estimated based on the closest years, see example in table 3.2 below.
5. If there is a gap of at least four years, in which the company is not a part of the survey, then single observations before or after the gap are deleted.

Table 3.2 – Imputation rules

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Company A	X	X	X	X	X	X	X	(2007+2009)/2	X	X
Company B	X	X	X	X	2006	X	2006	2009	X	X
Company C	X	X	X	X	X	2005	(2005+2009)/2	2009	X	2009
Company D		X (deleted)					X (deleted)			
Company E		X (deleted)				2007	X	(2007+2009)/2	X	2009
Company F	X	X	2002				X (deleted)			
Company G	X	X	2002			2007	X	(2007+2009)/2	X	2009

Source: DAMVAD

For Sweden we have only data for R&D investment in the odd years. Data for the even years have been interpolated. Missing observations in the odd years are imputed using the same imputations rules as for the other countries.

There are minor differences in the population of the R&D statistics between the countries. The Swedish R&D statistics only includes companies with at least 10 employees whereas the Finnish and Danish R&D statistic includes some companies with only two employees. The sample is not restricted to a common population bounded by the same company size across countries. We have utilized the full population to include information about as many research active companies as possible. In addition, we tested the elasticities from the full population and the restricted population and they are quite similar. For Finland they are 0.167 and 0.163 respectively.

3.2.2 DESCRIPTIVE STATISTICS

This study is conducted on panel data covering different statistics for the period 1999 to 2010. Descriptive statistics for each country are displayed in Appendix C.1. In the study the following statistics are used:

- Research and development statistics from 1999 to 2010 for Denmark, Finland and Norway and every two years for Sweden from 1999-2009.
- The national statistics behind the European Community Innovation Survey. The survey is conducted every two years in Finland, Norway and Sweden except for Denmark, where it is conducted every year. There is data for Denmark from 2006 to 2010, Finland and Norway for 2006, 2008 and 2010 and Sweden for 2008.
- Corporate statistics on company performance from 2004 to 2010 for all four countries.
- Educational statistics on employee educational levels from 2005 to 2010 for all four countries.

In the descriptive part of the study, the following has to be noted:

- Since there is only R&D statistics for Sweden every two years until 2009, in the benchmarking between the four Nordic countries 2009 data is used for Sweden and 2010 data for Denmark, Finland and Norway

- Working with the large amount of data collected for this study and writing the study has led to new idea on how to present the data. It has been possible for Denmark, Norway and Sweden to present data in another way because of access to micro data. Access to Finnish micro data can only happen at Statistics Finland. Due to limited time for conducting this study, Finland is unfortunately sometimes left out.

3.2.3 SECTOR CLASSIFICATION

Throughout the analysis, we will operation with a disaggregation of data at sector level. In Table 3.3 is an outline of the disaggregation of the different sector levels.

Table 3.3 – Sector and NACE code

SECTOR	NACE	DEFINITION
High tech industry	C	Chemicals (CE), Pharmaceuticals (CF), parts of Metals (CH(254)), Electronics (CI), Manufacturing of electrical equipment (CJ), Mechanical engineering (CK), parts of Transport and transportation equipment (CL) and parts of Other manufacturing (CM(325))
Medium and low industry	C	Natural resource extraction (B), Food, drink and tobacco (CA), Textiles and leather (CB), Wood, paper and printing (CC), Oil refineries etc. (CD), Plastics, gas and concrete (CG), parts of Metals (CH), parts of Transport and transportation equipment (CL), parts of Other manufacturing (CM), Energy (D) and Water and waste (E)
ICT	JA-JC	Publishing, TV and radio (JA), Telecommunications (JB) and IT and information services (JC)
Business services	MA-N	Consultancy and advisory services (MA), Research and development R&D (MB), Other business services (N)
Other services	G-I, K, L	Wholesale and retail trade (G), Transportation and storage (H), Accommodation and food service activities (I), Financial and insurance activities (K) and Real estate activities (L)
Other	A, F, O-X	Agriculture, forestry and fishing (A), Construction (F), Public administration, education and health (O-Q), Arts, entertainment and recreation (R-S) and Unspecified (X)

Source: OECD: ISIC REV. 3 Technology intensity definition

4. THE MICROECONOMIC IMPACTS OF INVESTMENTS IN BUSINESS R&D IN THE NORDIC COUNTRIES

The slowdown in productivity growth in the industrialised countries has increased the focus on how to improve productivity. Hence, in recent years policy makers, company managers, investors and economists in general have focused on the potential productivity gains from R&D investments.

R&D leads to the creation of new products, processes and services in businesses, increasing earnings and at the same time raising their level of knowledge. They will thus be more competitive in the long run to the benefit of productivity and growth. The aim of this chapter is therefore to measure and compare the impacts of business R&D investments, by estimating the labour productivity elasticities and the marginal returns with respect to business R&D investments at the company-level for Denmark, Norway, Sweden and Finland.

This study makes use of a unique and newly formed dataset for Denmark, Norway, Sweden and Finland (*the Nordic countries exclusive Iceland*) containing comparable company-level data, i.a. business R&D investments, employment (FTE) and productivity.

In the following sections the baseline model and the rate of return (reviewed in Section 3.1.2 and 3.1.7) is estimated in four different setups.

First of all, Section 4.1 estimates the rate of return at country level (4.1.1), sector level (4.1.2), company size (4.1.3) and green and welfare technology (4.1.4) for each of the four Nordic countries in question.

Secondly, Section 4.2 reports the elasticities to business R&D investments.

Text Box 4.1. Central terms

- *FTE* stands for full time equivalent – the number of full time employees
- *NACE* stands for *Nomenclature generale des Activites economiques dans les Communautes Européennes* and refers to the industrial classification
- *SMEs* are defined as companies which employs fewer than 250 persons. The European Union: "The new SME definition", 2005.
- *Productivity* is defined as the company's revenue plus other operating income minus consumption of products and services (inputs)
- *Labour productivity* is *productivity* divided by FTE

4.1 THE MARGINAL RETURN OF BUSINESS INVESTMENTS IN R&D

The marginal return on private R&D investments can be derived from the use of micro level data. Deriving the return requires knowledge about the relative coherence between value added and investments in R&D. This coherence is referred to as elasticity. In Chapter 4.2 we put forward the model that allows us to calculate the R&D elasticity to value added. Text Box 4.2 describes how to derive the return on investment based on the elasticity as well as absolute figures on R&D-investments and value added.

Text Box 4.2 – Calculation of the rate of return on business R&D investments

The underlying assumption when measuring the rate of return on business R&D investments is that R&D investments bring about new products and innovations that in return will increase the company's revenue. Rate of return is given by:

$$\rho = \gamma \cdot \frac{Y}{R_{t-1}} - \delta$$

Where γ is R&D elasticity, $\frac{Y}{R_{t-1}}$ is the median of value added to R&D capital (lagged one year) ratio, or the inverse R&D intensity in the company, and δ is the depreciation rate set to 15 percent which is the typical rate used in the literature.

COUNTRY	RATE OF RETURN ρ	R&D ELASTICITY γ	$\frac{Y}{R_{t-1}}$
Denmark	34.2 %	0.091	5.41
Finland	22.7 %	0.167	2.26
Norway	22.7 %	0.129	2.92
Sweden	16.4 %	0.107	2.93

4.1.1 THE MARGINAL RATE OF RETURN OF INVESTMENT BY COUNTRY

The rate of return on investing an additional euro in private R&D varies across the Nordic countries.

Table 4.1 shows the different return on investment in Denmark, Finland, Norway and Sweden. Swedish companies have the lowest return of investments, meaning that the median company in Sweden obtain a rate of return of the last invested euro in R&D of 16.4 percent. In other words, an extra euro invested in R&D equals an increase in value added on 1.16 euros and thereby 16 cents more on the bottom line for the Swedish median company. The return of R&D investments is 34.2 percent for Denmark and 22.7 percent for both Finland and Norway.

A test for different return of investment shows that the estimated rate of returns of business R&D is significantly different across the Nordic countries (except between Finland and Norway).[18] This result indicates that Denmark realizes a significantly higher return of investment in business R&D compared to Sweden, Norway and Finland.

Table 4.1 - Rate of return in the Nordic countries

COUNTRY	RATE OF RETURN OF THE LAST INVESTED EURO IN PRIVATE R&D
The median company in Denmark	34.2 %
The median company in Finland	22.7 %
The median company in Norway	22.7 %
The median company in Sweden	16.4 %

18 See appendix C.4.

4.1.2 THE MARGINAL RATE OF RETURN OF INVESTMENT BY SECTOR

There are both differences and similarities when we compare the return on investment in private R&D across sectors and countries. Whereas Finland yields higher returns in traditional manufacturing industries, both high tech and medium and low tech industries, Denmark and Norway yield higher returns in knowledge intensive business service (KIBS) sectors. Sweden yields a higher return in the ICT sector. The estimated marginal returns of R&D investments are summarised in Table 4.2.

Diminishing marginal return on investments might be a possible explanation for lower returns in some sectors compared to others. The low marginal return in the Swedish manufacturing sector might be due to a previously high level of investments in the sectors. We will see later on, that private R&D investment in traditional manufacturing industries in Sweden are diminished with almost 20 percent from 2005 to 2009, which correspond well with the low returns in the manufacturing sectors.

In Denmark and Norway, the private R&D investments in the KIBS sectors have increased. In Denmark with almost 40 percent from 2005 to 2009 and in Norway the investments have almost doubled, which also should be viewed in light of the high returns

An important point is that a high marginal rate of return on R&D investment in an sectors does not imply that the sectors in general has a high productivity growth. The service sector in Denmark (specifically the home oriented part) is characterized by relatively low productivity growth but have high returns on investments in R&D. The low productivity growth might be a consequence of too little investments in R&D and innovation. Thus, the high return might be a consequence of a low level of R&D investments in the past and illustrates that there are profitable investments, which has not yet been undertaken.

Table 4.2 - The marginal rate of return of business R&D investments by sectors at the country level

COUNTRY	HIGH TECH INDUSTRY	MEDIUM AND LOW TECH INDUSTRY	ICT	BUSINESS SERVICE	OTHER SERVICE	OTHER	TOTAL
Denmark	11.0 %	19.6 %	9.6 %	56.6 %	65.4 %	Insg.	34.2 %
Norway	9.5 %	15.3 %	5.8 %	34.6 %	109.1 %	49.8 %	22.7 %
Finland	18.8 %	26.3 %	1.8 %	13.3 %	6.0 %	60.4 %	22.7 %
Sweden	3.5 %	-1.2 %	24.9 %	10.2 %	3.1 %	108.3 %	16.4 %

4.1.3 THE MARGINAL RATE OF RETURN OF INVESTMENT BY COMPANY SIZE

Just as sector/industry specific characteristics, it is likely that company size also affects the company's return of investment. The estimated marginal returns of investments are summarised in Table 4.3. The marginal returns of investments are estimated as significant and positive for all company sizes and countries except from Swedish medium sized companies, i.e. between 50 and 99 employees and 100 to 250 employees, where the return of investment is negative.

For all four Nordic countries the return of business R&D investments are largest for companies with more than 250 employees. The larger the companies are the higher the return of investment. In the Nordic countries, large companies are three to four times more likely to engage in R&D compared to small and medium-sized companies (SMEs). In the four Nordic countries between 44 and 53 percent of the large companies are R&D performing, compared to between 9 and 17 percent among companies with less than 50 employees.

The difference in return of investment due to company size can result from the notion that companies with more than 250 employees have higher chances of implementing more risky R&D projects, where the prospect of investment returns is longer, and where there is a higher demand of liquidity and net worth, but where the return of investment is larger. It can also be that knowledge spillover gives a larger return of investment for large companies than for small, because fewer can have advantage of new knowledge and technology.

Table 4.3 - The marginal rate of return of business R&D investments by company size at the country level

COUNTRY	2-49 EMPLOYEES	50-99 EMPLOYEES	100-250 EMPLOYEES	MORE THAN 250 EMPLOYEES	TOTAL
Denmark	12.4 %	15.0 %	37.4 %	63.7 %	34.2 %
Norway	9.4 %	22.8 %	31.3 %	125.3 %	22.7 %
Finland	10.2 %	17.9 %	23.1 %	51.5 %	22.7 %
Sweden	4.9 %	-4.4 %	-7.6 %	24.6 %	16.4 %

4.1.4 THE MARGINAL RATE OF RETURN OF INVESTMENT IN GREEN TECHNOLOGY AND WELFARE TECHNOLOGY

With the increasing focus on the grand societal challenges as climate changes and aging of the population, more emphasis has been put on finding solutions to these challenges. New types of industries emerge in response to new business opportunities responding to the need to find new innovative solutions and new knowledge that can address the grand challenges.

Two emerging business areas, which arise in the aftermath of the new business opportunities, are businesses based on green and welfare technology. This section focuses on the development in these two new industrial sectors, which provide service as well as produce products.

In this section we estimate the rate of return of private R&D investments in the green technology and welfare technology sectors. Furthermore, we will compare the estimates of the rate of return within the welfare technology and welfare technology sectors. with the general level of the rate of return of R&D investments for the business sectors in the four countries.

This analysis employs a brand new and highly sophisticated method for measuring the welfare technology and welfare technology sectors. A weight is constructed on the industry level for both types of technologies indicating the level of activity in the production of that particular technology.

Construction of weights is a complex and resource demanding process. The Danish weights for green technology on the industry level are therefore also applied to Norway, Sweden and Finland. The Danish weights for welfare technology on the industry level are applied to Sweden and Finland, but not to Norway; Norway has its own weights calculated. When applying the Danish weights for the other Scandinavian countries it is implicitly assumed that industries that are green in Denmark, say 50 percent green, are also 50 percent green in the other Scandinavian countries.

As stated in the Chapter 3.1.8 the results should be seen as indications rather than exact results. We use a weight calculated at industry level and implement the weight on each individual company. As such we assume that all companies have the same weight as the industry. This is a strong assumption and we do not know the full consequence of the assumption.

Table 4.4 presents the return on investment from private R&D invested in green technology and in welfare technology. The marginal return on investments in private R&D vary across countries. The new estimations within the green technology and welfare technology sectors confirm this picture. The rate of return of the last invested euro, vary much more within these two sectors. For the welfare technology sectors, the rate of return varies from 2.2 percent in Sweden to 20.7 percent and 23.5 percent in Denmark and Finland respectively. The rates of return are significantly higher in Denmark and Finland compared to Sweden and Norway within the welfare technology sector.

The same picture can be found within the green technology sector although the rate of return is significantly higher in all countries compared to the welfare technology sector. The rate of return varies from 17.3 percent in Sweden to 33.5 and 34.5 percent in Denmark and Finland respectively. Again, the rate of return is significant higher in Denmark and Finland compared to Sweden and Norway.

Table 4.4 – The marginal rate of return in green technology and welfare technology

COUNTRY	GREEN TECHNOLOGY	WELFARE TECHNOLOGY	TOTAL
Denmark	33.5 %	20.7 %	34.2 %
Norway	24.7 %	11.5 %	22.7 %
Finland	34.5 %	23.5 %	22.7 %
Sweden	17.3 %	2.2 %	16.4 %

4.2 ESTIMATING THE R&D CAPITAL ELASTICITY

Knowing the relative coherence between R&D and value added is a prerequisite to estimate the return on private R&D investment. This section presents the results of estimating the relative coherence. This coherence is also known as the elasticity and is estimated through regression models.

The regression models are well described in the literature, see Hall, et.al. (2009), The Danish Agency for Science, Technology and Innovation (2010) as well as Bjørner & Mackenhauer (2011). We follow this tradition and assume that the production function productivity can be approximated by the following augmented Cobb-Douglas function including physical capital C, labour L, R&D or knowledge capital R and export intensity X[19]:

$$Y_{i,t} = Ae^{\lambda t}\, C_{i,t-1}^{\alpha}\; L_{i,t}^{\beta}\, R_{i,t-1}^{\gamma} X_{i,t-1}^{\sigma} e^{\varepsilon}$$

According to the Cobb-Douglas function, the company's output Y or value added[20] is determined by the four inputs.

The model is then estimated after the usual log-transformation converting it into a linear model:

$$\ln(Y_{it}) = a_B + \lambda_t + \alpha \ln(C_{i,t-1}) + \beta \ln(L_{i,t}) +$$

$$\gamma \ln(R_{i,t-1}) + \sigma \ln(X_{i,t-1}) + \varepsilon_{i,t}$$

The coefficients measure the elasticity of value added with respect to physical capital, labour and R&D and export intensity. And hence they are describing the marginal effect of the inputs on the output variable. The empirical model then becomes:

$$\ln\left(\frac{Y_{i,t}}{FTE_{i,t}}\right) = a_B + \lambda_t + \alpha \ln\left(\frac{C_{i,t-1}}{FTE_{i,t}}\right) + \beta \ln(FTE_{i,t}) +$$

$$\gamma \ln\left(\frac{R_{i,t-1}}{FTE_{i,t}}\right) + \sigma \ln(X_{i,t-1}) + \varepsilon_{i,t}$$

Where $\boldsymbol{aB}$ and $\boldsymbol{\lambda t}$ are dummy variables that capture any sector and time specific effects, respectively. The baseline model explains company i's labour productivity in year t as function of company i's current labour force (FTE) and the physical capital, R&D capital and export intensity from the previous year t-1.

It is essential to distinguish between stock and flow variables in the model. The focal point of this analysis is the coefficient to the R&D **capital stock** (γ), i.e. the accumulation of past R&D investments, which is not to be confused with the present level of R&D investments, a **flow** variable. The estimated coefficient of R&D capital (γ) is in this functional form interpreted as the elasticity of R&D capital. This elasticity is interpreted as the percentage increase in value added per employee when R&D capital increases by one percent. A positive elasticity of R&D capital means that an increase in R&D capital will increase the value-added per employee. A significant elasticity can be used to estimate the return on investment in private R&D.

4.2.1 R&D CAPITAL ELASTICITY BY COUNTRY

The estimated R&D labour productivity elasticities are positive and significant for the companies in all four Nordic countries. Furthermore, the sizes of the elasticity are within the normal bounds as described by the literature.[21] When comparing the R&D elasticities, it is apparent that the elasticities vary across the Nordic countries. Denmark and Sweden have the lowest R&D elasticities of 0.091 and 0.107 respectively. There is no significant difference in the elasticities of the two countries.[22] Conversely, Norway and Finland have the highest R&D labour productivity elasticities of 0.129 and 0.167 respectively.

The R&D elasticity expresses the percentage increase in labour productivity, which follows a one-percentage in-

19 Export intensity = Export / Revenue

20 Value added is a measure of output, and is defined as Value added = value of production – Intermediate consumption. Value added is comparable across countries and economic institutions.

21 Hall et al. (2009).

22 See appendix A.2

crease in the R&D capital stock in the business sector. For instance, an elasticity of 0.15 expresses that an increase in business R&D capital stock by one percent creates an average increase in labour productivity by 0.15 percent in the business sector.

The physical capital elasticities, as shown in Table 4.5, are positive and significant. For the majority of the countries, with Finland being the only exception, the physical capital elasticities higher are than the R&D elasticities. This is a typical finding in the literature see e.g. Harhoff (1998). In the case of Sweden, the physical capital elasticity is more than twice as large as the R&D elasticity. This might be explained by the composition of the Swedish industry, but it would require further analysis to identify which industry patterns could count for this explanation.

Table 4.5 - General average company performance in the Nordic countries

	DENMARK	NORWAY	FINLAND	SWEDEN
Log (R&D capital/FTE)	0.091***	0.129***	0.167***	0.107***
Log (Physical capital/FTE)	0.132***	0.132***	0.142***	0.226***
Log(FTE)	-0.002	0.006	-0.008*	-0.067***
Constant	10.097***	10.053***	8.119***	9.410***
Export intensity	Yes	Yes	No	Yes
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
R-sq.	0.322	0.401	0.3446	0.4612
N	5,744	4,584	6,440	4,048

***, ** and * indicate significance at the 1, 5 and 10 percent level.
Notes: Export data is not available for Finland. The parameter estimates are not strongly affected when adjusting for the quality of the labour force, see Appendix A.2.

4.2.2 R&D CAPITAL ELASTICITY BY SECTORS

The estimated R&D elasticities at sector level are summarised in Table 4.6. The R&D elasticities are positive and significant for all sectors and countries, with *Other* in Denmark being the only exception. The R&D elasticities vary across sectors and countries. Despite the variation in the R&D elasticities, there are some sectors across the Nordic countries that consistently have a higher elasticity than others do.

It is difficult to conclude something meaningful by comparing the elasticities across sectors. The elasticity shows a relative coherence between two variables. In order to conclude something meaningful the analysis need to encounter the cost of a relative change in the investment variable, i.e. R&D investments. Thus a 100 percent increase cost one billion euros if the change is from one billion euros in R&D capital to two billion euros. whereas the same increase cost 10 billion euros if the change in capital is from 10 billion euros to 20 billion euros. The important result is thus, that regardless of sector and country we see, that investing more in R&D implies a higher value added per employee. Thus investing in knowledge and technology increases the productivity of your employees. Results from the full model are presented in Appendix C.3.

Table 4.6 - Ranking of R&D elasticities by sector

COUNTRY	HIGH TECH INDUSTRY	MEDIUM AND LOW TECH INDUSTRY	ICT	BUSINESS SERVICE	OTHER SERVICE	OTHER	TOTAL
Denmark	0.090***	0.032***	0.147***	0.120***	0.075***	Insg.	0.091***
Norway	0.111***	0.075***	0.164***	0.170***	0.153***	0.063***	0.129***
Finland	0.206***	0.084***	0.241***	0.215***	0.106***	0.086***	0.167***
Sweden	0.103***	0.020***	0.210***	0.257***	0.079***	0.125***	0.107***

Note: The regression model is equal to the models presented in Table 4.5.

4.2.3 R&D CAPITAL ELASTICITY BY COMPANY SIZE

Just as sector specific characteristics, it is likely that company size also affects the company's ability to transform R&D investments into increased labour productivity. Larger companies tend to have higher labour productivity. This is due to better use of labour as an input and economies of scale. Hence, it is likely that differences in company size will influence the elasticities.

Several past studies have touched upon this subject. For example Pagano and Schivardi (2003) consider a set of European countries, and find that average company size has a positive effect on growth at the industry level. Lichtenberg and Siegel (1991) find that the rates of return to R&D investments are increasing with company size. These results indicate that larger companies capitalize the gains of innovations more efficiently compared to smaller companies. Also, in recent years a consensus seems to have emerged among policy makers, that small and medium sized companies (SME) play a crucial role for the economic development of nations and regions.[23] This political focus on SMEs has brought about a myriad of public subsidy schemes aiming at the R&D activity in SMEs throughout the EU. Given this focus on SME this section analyses the effect of company size on R&D elasticities in the Nordic countries. In the following the companies are divided into four groups with respect to company size: 2-49 employees, 50-99 employees, 100-250 employees and more than 250 employees.

The estimated R&D elasticities are summarised in Table 4.7. The R&D elasticities are estimated as positive and significant for all company sizes and countries. Except for company size 100-250, Finland and Norway have the largest R&D elasticities in every group. The full models are presented in Appendix C.3.

Table 4.7 - R&D elasticities by company size

COUNTRY	2-49 EMPLOYEES	50-99 EMPLOYEES	100-250 EMPLOYEES	MORE THAN 250 EMPLOYEES	TOTAL
Denmark	0.106***	0.043***	0.064***	0.095***	0.091***
Norway	0.175***	0.093***	0.051***	0.101***	0.129***
Finland	0.219***	0.090***	0.091***	0.142***	0.167***
Sweden	0.110***	0.058***	0.029***	0.078***	0.107***

Note: The regression model is equal to the models presented in Table 4.5.
There are minor differences in the composition of the R&D statistics for companies with less than 10 employees between the countries. The elasticity for "2-49" is however only slightly affected if companies with less than 10 employees are excluded. For Finland the elasticity is 0.219 and 0.185 respectively.

4.2.4 R&D CAPITAL ELASTICITIES OF GREEN TECHNOLOGY AND WELFARE TECHNOLOGY

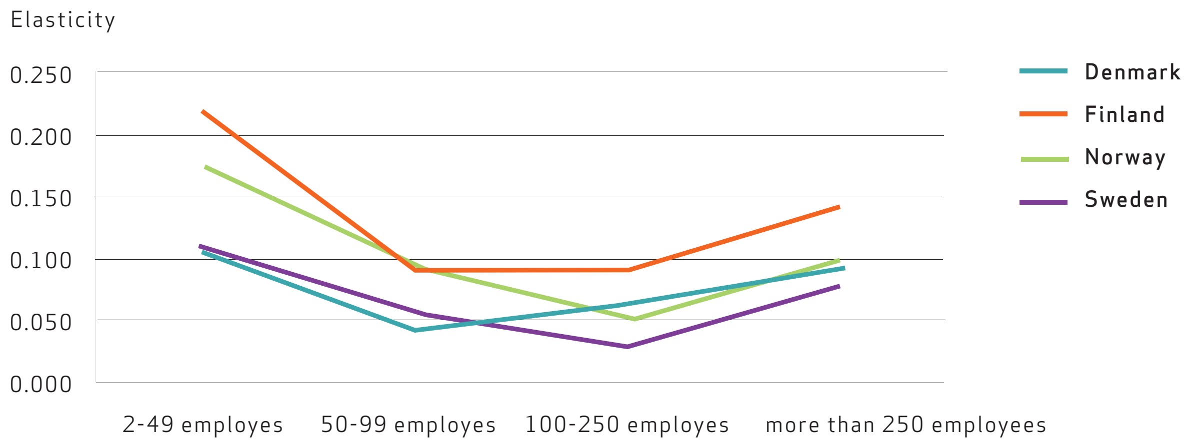
There is a positive correlation between investing more in green or welfare technologies and productivity. Table 4.8 shows the elasticities of both green technology and welfare technology are positive and significant across countries. The R&D elasticity of investments in welfare technology is higher than the elasticity of investments in green technology in Denmark, Norway and Finland, but not in Sweden. The elasticity of the welfare technogoly is 0.105 in Sweden, 0.144 and 0.155 in Denmark and Norway respectively and 0.241 in Finland. Results from the full model are presented in Appendix C.3.

Table 4.8 – R&D labour productivity elasticities in green technology and welfare technology

COUNTRY	GREEN TECHNOLOGY	WELFARE TECHNOLOGY
Denmark	0.118***	0.144***
Norway	0.122***	0.155***
Finland	0.193***	0.241***
Sweden	0.110***	0.105***

Although the overall levels of the R&D elasticities vary among the countries, their internal ranking of the R&D elasticities is quite similar. Company size 2-49 and more than 250 respectively are the largest and second largest in all four countries. This result indicates that it is the smallest and largest companies that realize the largest labour productivity gains from an additional increase in R&D capital compared to the medium sized companies (50-99 and 100-250 employees) in the Nordic countries, see Figure 4.1. Again, the comparison between the different groups should be taken with caution. It is likely that a 100 percent increase in R&D capital is cheaper amongst the smaller companies than among the bigger.

Figure 4.1 - R&D labour productivity elasticities by company size



23 SMEs are defined as companies which employ fewer than 250 persons, EU (2005).

The objective of companies R&D investments is to increase the company's stock of knowledge in order to find new applications and innovations.[24] Because new applications of technology and innovations are associated with increased productivity and turnover, cross country comparison of business R&D investments are often used to analyse the underlying growth potential of countries.

Against the background of the econometric analysis of the economic **returns** of business R&D investments, as presented in Chapter 4, it is useful to take a closer look on how the Nordic countries perform with respect to the overall developments in busines R&D investments. Moreover, this section will provide evidence on the historical development of business R&D investments for the period 2005-2010 and compare a group of selected R&D indicators across Denmark, Finland, Norway and Sweden. The indicators presented in this chapter mainly describe the R&D performance of the Nordic countries at country and industry level and by company size.

Text Box 5.1 - Definition of research and development (R&D)[25]

The main aggregate used for international comparisons of business R&D investments is gross expenditure on R&D (GERD).

GERD data and their components are compiled on the basis of the OECD Frascati Manual 2002 methodology, which 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 stock of knowledge to devise new applications".

GERD is usually broken down among four sectors of performance: company, higher education, government and private not-for-profit institutions serving households (PNP). GERD is often reported in relative terms as a percentage of GDP, to denote the R&D intensity of an economy. Regional R&D intensity is defined as total intramural investments on R&D performed in the sub-national territory (the region) in a given year, and it is defined relative to regional GDP.

DEFINITION OF COMPANIES R&D INVESTMENT

Company investment in R&D (BERD) covers R&D activities carried out in the business sector by performing companies and institutes, regardless of the origin of funding. The company sector includes:

- All companies, organisations and institutions whose primary activity is the production of goods and services for sale to the general public at an economically significant price.
- The private and not-for-profit institutions mainly serving them.

24 Hall et al. (2009)

25 OECD 2011, OECD Science, Technology and Industry Scoreboard 2011 – Innovation and Growth in Knowledge Economies

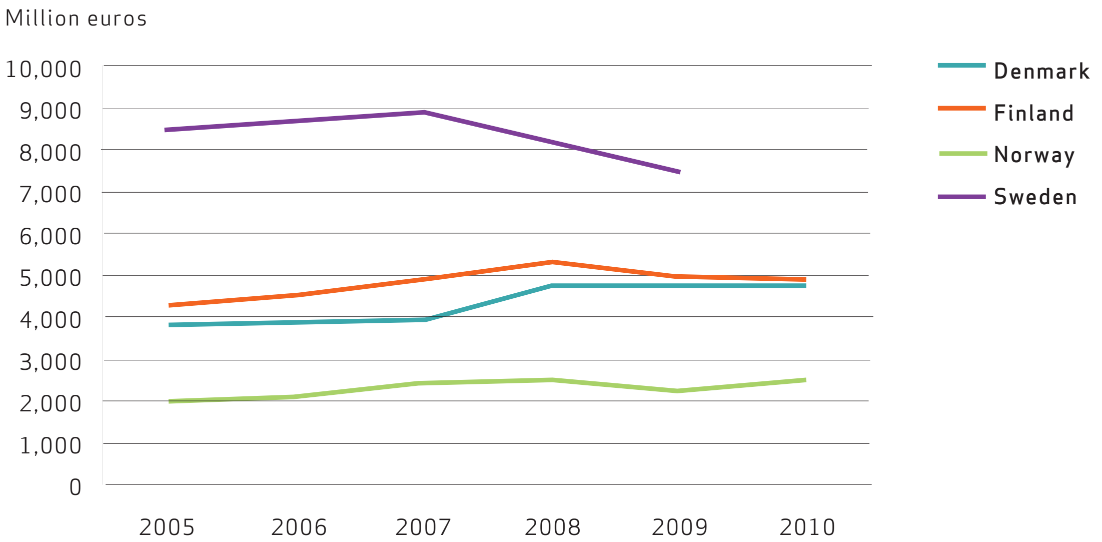
5.1 BUSINESS R&D INVESTMENT BY COUNTRY

To illustrate the overall business R&D effort in the Nordic countries, we first compare the volume of business R&D investment in Figure 5.1. In 2009[26] the total amount of business R&D investments in the four Nordic countries amounted to 19.5 billion euros. According to Figure 5.1 Sweden had the largest share of 38 percent, corresponding to 7.5 billion euros in 2009. Finland and Denmark had an almost equal share of 25 and 24 percent respectively, corresponding to 5 and 4.8 billion euros. Norway had a share of 12 percent corresponding to 2.3 billion euros.

Since 2007 and 2008 Sweden and Finland's business R&D investments have been declining. Conversely, Denmark appears to have increased its business R&D investments in the same period until 2009 where business R&D investments have declined marginally. In 2010 Denmark almost equaled Finland in terms of business R&D investments.

From 2005 to 2010 Denmark and Norway had an average yearly growth rate in business R&D investments of 4.7 percent. Finland had an average yearly growth rate of 2.7 percent. Sweden had a negative average annual growth rate of -2.9 percent from 2005 to 2009. Sweden and Finland, who on average invested the largest amount on business R&D, also experienced the largest decrease in business R&D investments during the period.

Figure 5.1 – Business R&D investment, 2005-2010



Note: Data for Sweden is only available in uneven years. Data in even years is interpolated (an average on the two nearby years). Fixed 2010-prices.

In any cross-country comparison of business R&D investments it is important to adjust for country size in order to eliminate any bias in the R&D data. This can be done in several ways. In the following we will present business R&D investments adjusted to Gross Domestic Product (GDP).

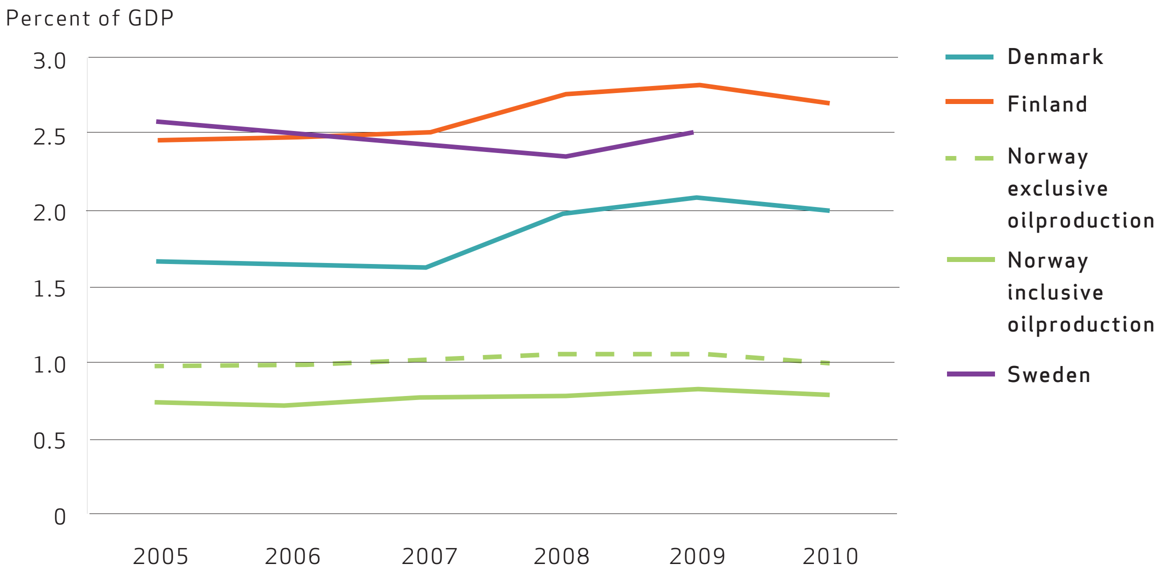
Figure 5.2 shows business R&D investments as percentage of GDP in the Nordic countries from 2005 to 2010. Finland and Sweden's R&D investments accounts for approximately 2.5 percent of their GDP. However Finland's share has been increasing in 2008 and 2009 and accounts for 2.7 percent in 2010. Denmark's share also increased during the period from 1.6 percent in 2007 to 2.08 percent in 2009, but decreased to 2.01 percent in 2010. Overall Finland, Sweden and Denmark allocate more resources on R&D measured as percentage of GDP than the EU-25[27].

Norway is the only Nordic country investing less in business R&D than the EU-25 average. In 2010 Norway invested around 0.8 percent of its GDP in business R&D. However, Norway's GDP is extraordinarily high due to the country's production of oil and gas. If this is taken into account, Norway spends around one percent of its GDP on business R&D investments.

26 There is only data for Sweden in odd years.

27 In 2010 total business R&D investments in the EU-25 accounted for 2 percent of their total GDP.

Figure 5.2 - Business R&D investments as percentage of GDP, 2005-2010



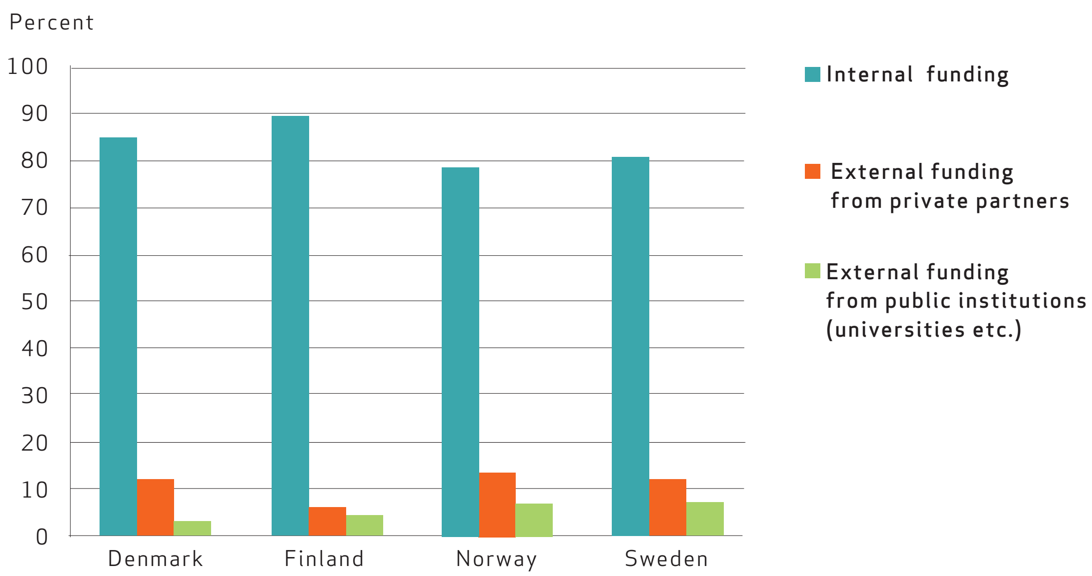
Note: Data for Sweden is only available in uneven years. Data in even years is interpolated (an average on the two nearby years).

5.1.1 SOURCE OF FUNDING OF BUSINESS R&D INVESTMENTS

The funding of business R&D investments may come from internal or external sources, such as private companies, public institutions (government and higher education) or within the company itself.

Figure 5.3 shows the different sources of funding of business R&D investments in the Nordic countries in 2009. Around 80 percent of the business R&D investments in Denmark, Norway and Sweden are internally funded, while 89.1 percent of Finland's business R&D investments are internally funded. External funding from private partners constitutes between 12 and 14 percent of the business R&D investments in Denmark, Norway and Sweden, while it is 6 percent in Finland. Norway and Sweden are the two Nordic countries with the largest share of external funding from public institutions with approximately 7.5 percent, while it is 3.0 and 4.7 percent in Denmark and Finland.

Figure 5.3 – Private R&D investment by source of funds in 2009



5.2 BUSINESS R&D INVESTMENT BY INDUSTRY

In order to get more detailed knowledge on how the Nordic countries differ with respect to business R&D investment, this section describes the distribution of business R&D investments on selected industries in 2010. The industry classification used corresponds to the NACE classification, see Text Box 4.1.

Table 5.1 compares the top 10 industries with respect to business R&D investments and shows notable variations between the four Nordic countries. The Finnish electronics industry had a total of 2.584 billion euros in 2010 and accounted for slightly over half of the total business R&D investments in Finland, which is the highest intensity among the Nordic countries.

Unlike the rest of the Nordic countries the top five industries in Denmark all have a share higher than 10 percent and a total of 69 percent. In Finland it is only the Electronics that has a share higher than 10 percent, however the total business R&D investments for top five industries amounts to 74 percent. The top five industries in Sweden and Norway have a total share of 73 and 50 percent respectively.

In total the top 10 industries account for 90 percent of the total business R&D investments in Denmark, followed by 86 percent in Finland, 74 percent in Norway and 92 percent in Sweden.

Table 5.1 -Top 10 industries with largest R&D investments in percent of total business R&D investments in 2010

RANKING	DENMARK		FINLAND		NORWAY		SWEDEN	
1	Pharmaceuticals	20%	Electronics	53%	IT and information services	14%	Pharmaceuticals, Research and development (R&D), Electrinics and Oil refineries*	47 %
2	IT and information services	13%	Mechanical engineering	7%	Consultancy and advisory services	12%	Transport and transportation equipment	19%
3	Mechanical engineering	13%	IT and information services	6%	Publishing. TV and radio	9%	Real estate activities	7%
4	Research and development (R&D)	12%	Manufacturing of electrical equipment	5%	Food. drink and tobacco	9%	Mechanical engineering	7%
5	Financial and insurance activities	11%	Consultancy and advisory services	3%	Electronics	6%	IT and information services	4%
6	Electronics	7%	Chemicals	3%	Metals	5%	Wholesale and retail trade	3%
7	Chemicals	5%	Wood. paper and printing	2%	Research and development (R&D)	5%	Metals	3%
8	Wholesale and retail trade	4%	Research and development (R&D)	2%	Chemicals	5%	Other manufacturing	2%
9	Consultancy and advisory services	3%	Pharmaceuticals	2%	Telecommunications	4%	Chemicals	2%
10	Other manufacturing	3%	Metals	2%	Financial and insurance activities	4%	Manufacturing of electrical equipment	1%

Note: 2010 data from Denmark, Finland and Norway and 2009 data from Sweden.
*In Sweden the industries *Electronics, Research and development (R&D), Pharmaceuticals and Oil refineries* are not included individually due to discretion because single large company dominates the whole industry.
Sweden does not collect statistics for R&D investments in the industry *Financial and insurance activities*.

5.2.1 DEVELOPMENT IN THE TOP FIVE INDUSTRIES

The top five R&D industries in 2010 have increased their share of total business R&D investments from 2005 to 2010 in Denmark, Sweden and Norway (Finland are not inculded in this section due to data limitation). This indicates that other industries are lacking behind.

According to Figure 5.4 the 2010 top five R&D industries in Denmark have grown in total from 2005 to 2010. In 2005 they accounted for 55 percent of the total business R&D investments, but in 2010 the five industries constitute 69 percent of the total business R&D investments. These five industries represent an increasing share of the total business R&D investments, primarily due to increases in Financial and insurance activities and Research and development.

The industry Financial and insurance activities has for example increased its share the most from 3.4 percent in 2005 to 10.9 percent of total business R&D investments in 2010. Conversely, the share of total R&D investments for Pharmaceuticals and IT and information services, have either fallen slightly or remained constant. The share of total R&D investments in Mechanical engineering risens sharply from 2009 to 2010, due to a change in the method of accounting.

In Sweden the share of the top five R&D industries have grown from 70 to 73 percent of the total business R&D investment from 2005 to 2009, see Figure 5.5.

Figure 5.4 - Development in the 2010 top five industries R&D investment as a percentage of total business R&D investment in Denmark

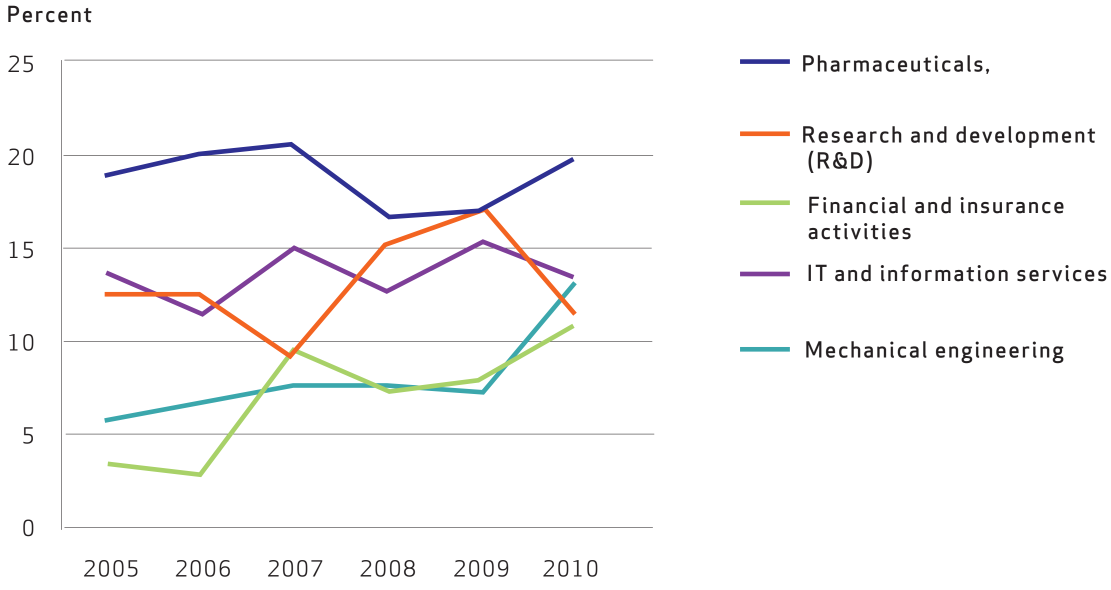
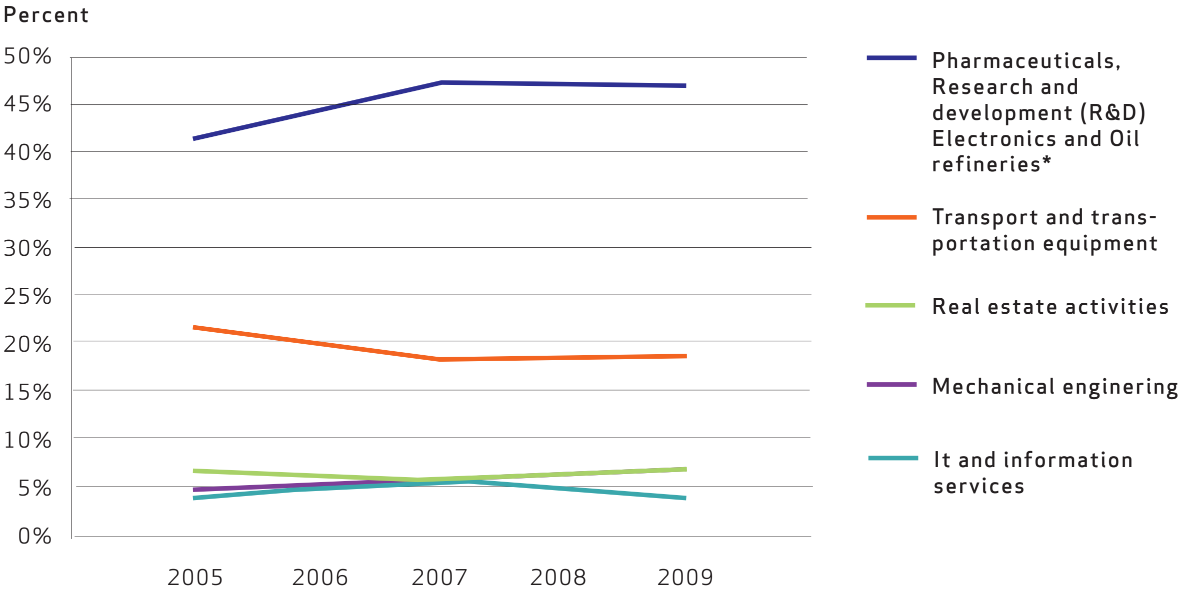


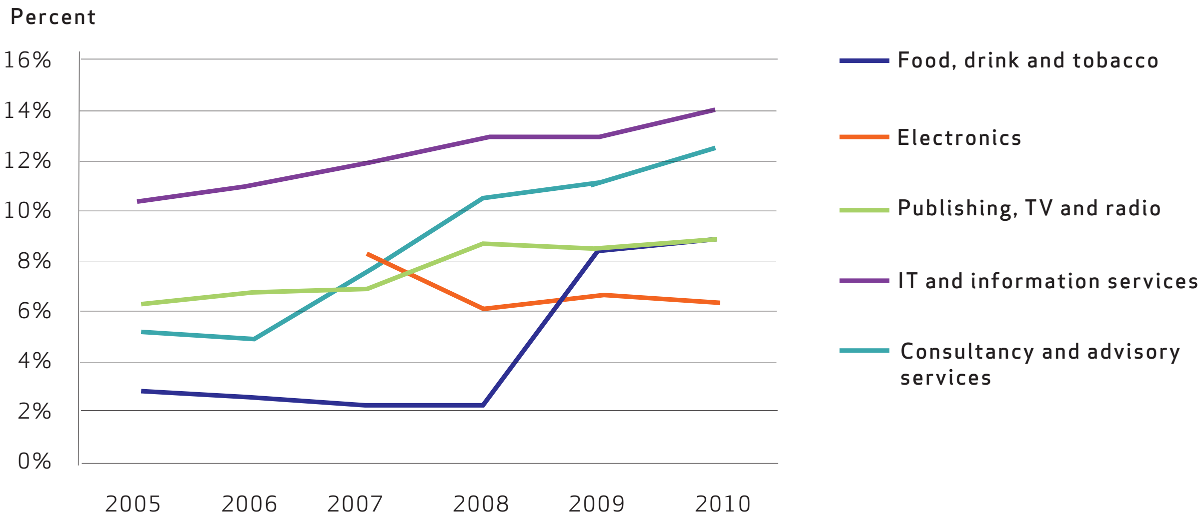
Figure 5.5 - Development in the 2009 top five industries R&D investment as a percentage of total business R&D investment in Sweden



Note: Data for Sweden is only available in uneven years.
*In Sweden the industries *Electronics, Research and development (R&D), Pharmaceuticals and Oil refineries are not included individually* due to discretion because single large company dominates the whole industry.
Sweden does not collect statistics for R&D investments in the industry *Financial and insurance activities.*

In Norway the share of the top five R&D industries have grown from 37 to 51 percent of the total business R&D investment from 2007 to 2010. There has been a high degree of specialisation in Norway in R&D over the last four years. On average there has been an increase in the five industries' R&D investment on 42 percent over the last four years. In the same period the total private R&D investment has increased with three percent, see Figure 5.6.

Figure 5.6 - Development in the 2010 top five industries R&D investment as a percentage of total business R&D investment in Norway.



Note: There is a shift in industry classification in Norway in 2007, which has not fully been accounted for in "Electronics". Therefore the Electronics industry is not shown before 2007.

5.2.2 R&D INVESTMENTS BY SECTOR

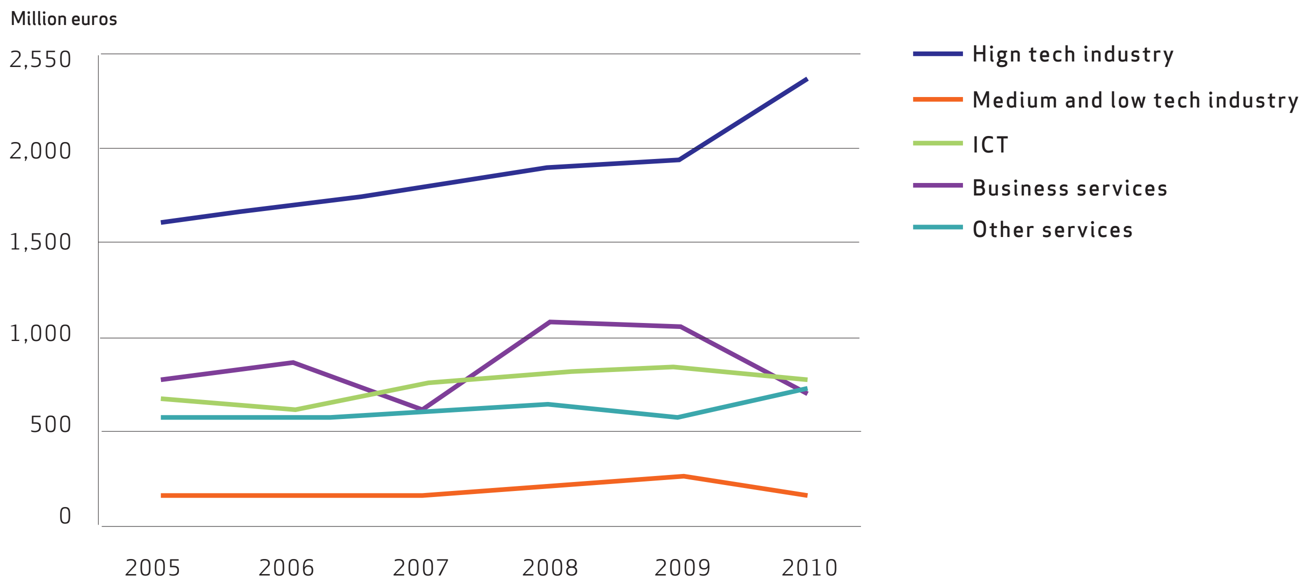
On a more aggregate industry level the companies from the *High tech industry* have the largest investment in R&D for all the four Nordic countries, see Table 5.2. The *High tech industry* includes industries as *Pharmaceuticals, Electronics and Transport and transportation equipment*. In Finland, the *High Tech industry* represents 75 percent of the total business R&D investments. In Sweden and Denmark, the share is 66 and 41 percent respectively. Norway is the country where the R&D investments are most equally distributed between the business sectors: Medium and low tech industry, *ICT and Business services*. Only 30 percent of the total business R&D is invested in the Norwegian *High tech industry*.

Table 5.2 - Business R&D investments in percent of total business R&D investments in 2010 by sector level

SECTOR	DENMARK 2010	NORWAY 2010	FINLAND 2010	SWEDEN 2009
High tech industry	41%	30%	75%	66%
Medium and low industry	4%	13%	6%	5%
ICT	16%	28%	9%	9%
Business services	22%	21%	5%	13%
Other services	18%	8%	3%	6%
Other	0%	1%	1%	1%

From 2009 to 2010 the R&D investments in the Danish High tech industry increased from 1,935 to 2,366 million euros corresponding to a 22 percent increase, see Figure 5.7. The High Tech industry also has the highest R&D intensity compared to the other sectors. Over the years 2005 to 2010 there has been relatively large variation in the development in private R&D investment in the Business services industry.

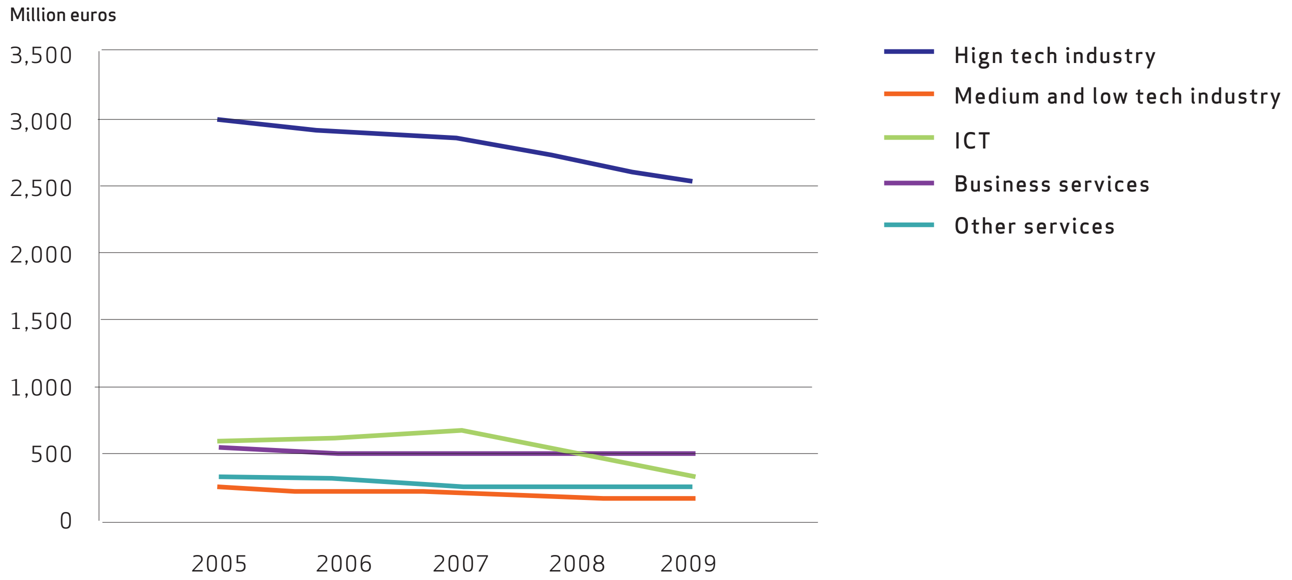
Figure 5.7 - Development in business R&D investment in Denmark by sector level, 2005-2010



Note: Fixed 2010-prices

In Sweden the business R&D investment in High Tech industry and ICT are decreasing, see Figure 5.8. The rate of return for ICT is still high compared to other sectors in Sweden despite the decreasing investment in ICT on 45 percent since 2005. This may be due to a time lag between the business investment in R&D and rate of return. Sweden has a high R&D intensity in the High tech industry and in Business services industry. Even though the R&D investment in the High tech industry is decreasing, it still has the highest R&D intensity in Sweden.

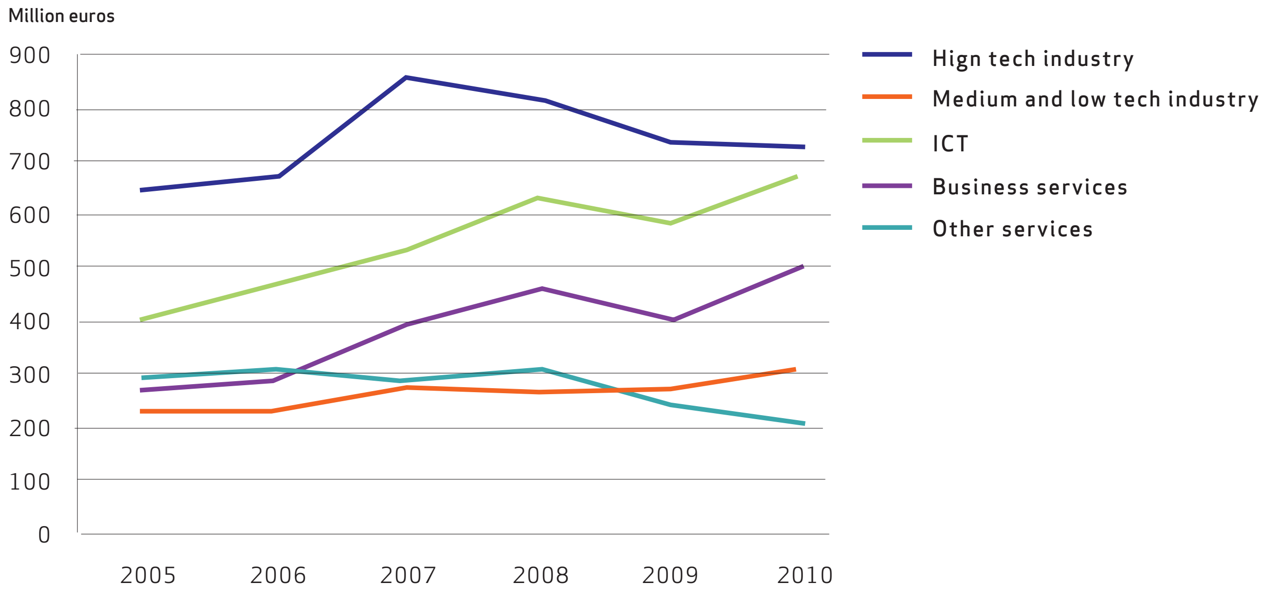
Figure 5.8 - Development in business R&D investment in Sweden by sector level, 2005-2009



Note: Fixed 2010-prices
Data for Sweden is only available in uneven years.

Compared to Sweden and Denmark, Norway has had a strong increase in private R&D investments in ICT from 409 million euros in 2005 to 674 million euros in 2010 corresponding to a 65 percent increase, see Figure 5.9. On the other hand the private investments in the high tech industry seem to follow the pattern of Sweden.

Figure 5.9 - Development in business R&D investment in Norway by sector level, 2005-2010



Note: Fixed 2010-prices

5.3 BUSINESS R&D INVESTMENT BY COMPANY SIZE

In the following section, the business R&D investments are described for four different company categories for each of the Nordic countries. The categories are defined by the company size with respect to number of full time employees, and are identical to those used in the econometric analysis in Chapter 4.

Table 5.3 shows that there is considerable variation in the share of business R&D investments among company size. The largest companies (250 or more employees) account for the largest share of business R&D investments in the Nordic countries even though there is also considerable variation in the total amounts invested in R&D by large companies (250 or more) in the Nordic countries. In Norway, large company invested 751 million euros in R&D, in Sweden large companies invested around eight times as much, corresponding to 5,981 million euros. In Denmark and Finland, large companies invested 3,420 and 3,889 million euros in R&D respectively.

Table 5.3 – Business R&D investments as percentage of total R&D in 2010 by size of company

COMPANY SIZE	DENMARK	NORWAY	FINLAND	SWEDEN
2-49 employees	16.6 %	32.8 %	9.9 %	7.0 %
50-99 employees	5.5 %	12.2 %	4.1 %	4.2 %
100-250 employees	5.8 %	19.7 %	5.3 %	7.8 %
More than 250 employees	72.1 %	35.3 %	80.7 %	81.0 %

Note: Data for Sweden is only available in uneven years. 2010 data is not available. 2009 data used instead.

The smallest companies account for the second largest shares in Denmark, Norway and Finland, while in Sweden they only account for the third largest share. Overall, the distributions of business R&D investments are quite similar for Denmark, Finland and Sweden, where the largest companies' share is between 72 and 81 percent. Norway have a somewhat equal distribution of business R&D investments across company sizes, hence the largest and smallest companies account for an almost equal share of 32.8 and 35.3 percent. In other words, Norway lack R&D investments from large companies compared to the other Nordic countries even though Norway has the same share of R&D active companies.

For Sweden and Denmark, the 10 companies with the largest share of R&D investments stands for 53.5 and 40.1 percent of the total business R&D investments. This is only 24.2 percent for the top 10 Norwegian companies. Norway is the Nordic country with the most equal distribution of business R&D investments across company size and industry, but lack large companies that invest in R&D compared to the other Nordic countries.

Table 5.4 shows that large companies in Denmark, Norway and Sweden are three to four times more likely than small and medium-sized companies (SMEs) to engage in R&D. In the three Nordic countries between 44 and 53 percent of the large companies are R&D-active, compared to between 12 and 19 percent of the SMEs. Totally, with 19 percent Denmark has the largest share of R&D active companies, followed by Norway and Sweden with 14 and 13 percent, respectively.

Table 5.4 - Share of companies with R&D activity in 2010 by size of company

COMPANY SIZE	DENMARK	NORWAY	SWEDEN
2-49 employees	17%	12%	9%
50-250 employees	27%	27%	24%
2-249 (SME) employees	19%	14%	12%
More than 250 employees	46%	44%	53%
Total	19%	14%	13%

Note: Data for Finland is not available.

Data for Sweden is only available in uneven years. 2010 data is not available. 2009 data used instead.

5.3.1 HUMAN R&D CAPITAL BY COMPANY SIZE

R&D employment is a useful indicator of business R&D investments, when comparing R&D efforts across countries. Table 5.5 shows the R&D employment as percentage of total employment by company size in each of the Nordic countries.

Table 5.5 – Share of R&D employees as percentage of total employment in 2010 by company size

COMPANY SIZE	DENMARK	NORWAY	FINLAND	SWEDEN
2-49 employees	0.8 %	1.0 %	1.3 %	0.7 %
50-99 employees	0.2 %	0.4 %	0.4 %	0.4 %
100-250 employees	0.3 %	0.5 %	0.5 %	0.7 %
More than 250 employees	2.8 %	0.8 %	4.1 %	5.3 %

Note: Data for Sweden is only available in uneven years. 2010 data is not available. 2009 data used instead.

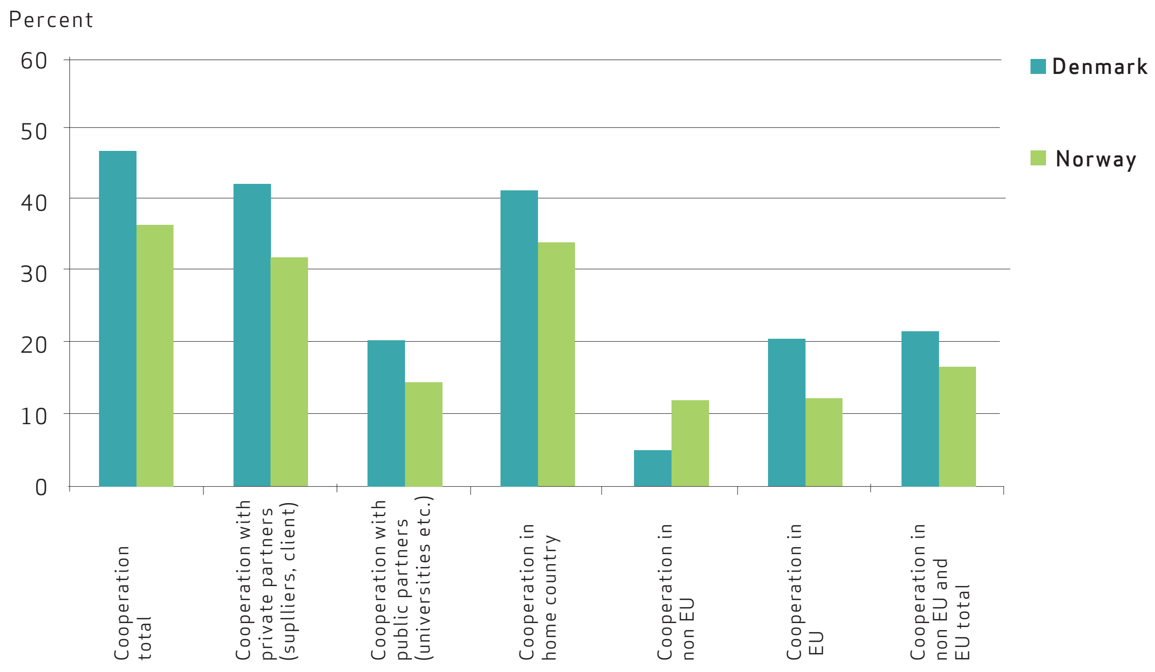
R&D employees are full time equivalent (FTE).

5.4 R&D COLLABORATION

R&D collaboration is often seen as a way to increase the effect of R&D investments. In addition to buying information from other companies or institutions, collaboration may be a key source of knowledge transfers. In particular, collaboration with public research organisations (higher education or government research institutions) can be an important source of knowledge transfer between science and industry. The Danish Agency for Science, Technology and Innovation showed in 2011 that collaboration with a knowledge institution increased the labour productivity in R&D-active companies with 9 percent a year. In addition, studies from The University of Copenhagen (2012) and the Technical University of Denmark (2012) have proved that companies entering into collaboration with the universities increased their labour productivity.[28] Hence, it is worthwhile to focus on R&D collaboration.

It was not possible to collect data on R&D collaboration for Sweden and Finland. According to Figure 5.10, in 2009 48 percent of the Danish R&D active companies have R&D collaboration while 37 percent of the Norwegian R&D active companies have R&D collaboration. R&D collaboration with for example suppliers, clients and customers is used more often than R&D collaboration with public actors as universities. Most of the R&D collaboration happens with partners from the company's home country. Norwegian companies collaboration with foreign partners are equally divided between partners from the EU (13 percent) and non-EU countries (13 percent) while Danish companies collaborate more with partners from the EU (21 percent) than non-EU countries (5 percent).

Figure 5.10 - Share of R&D active companies with R&D collaboration in 2009



Note: Data for Finland and Sweden are not available.

28 The effect of collaboration with the University of Copenhagen is a labour productivity gain of 6.5 percent a year. The corresponding effect for The Technical University of Denmark is 10 percent a year.

According to Table 5.6 companies with more than 250 employees are significantly more likely to collaborate on R&D than SMEs. 58 percent of the Danish companies with more than 250 employees collaborate, while 41 percent of companies with 100-250 employees collaborate. In Norway 59 percent of the companies with more than 250 employees, collaborate, while 39 percent of companies with 100-250 employees collaborate.

Table 5.6 – Share of R&D active companies with collaboration in 2010 by company size

COMPANY SIZE	DENMARK	NORWAY
2-49 employees	30%	32%
50-99 employees	31%	37%
100-250 employees	41%	39%
More than 250 employees	58%	59%

Note: Data for Finland and Sweden is not available.

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APPENDIX A - COMPANY INNOVATION IN THE NORDIC COUNTRIES

This appendix describes the innovative performance of the Nordic countries. As such, it provides insight into the understanding of the effects of business R&D investments in the Nordic countries. As shown in the previous chapters, business R&D investments are not only important drivers of labour productivity growth, but also one of the main drivers of the innovative performance of the companies.

Text Box A.1 - Definition of innovation (the Oslo Manual)

The latest (3rd) edition of the *Oslo Manual* defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. This implicitly identifies the four types of innovation:

Product innovation: the introduction of a good or service which is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

Process innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

Marketing innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

Organisational innovation: the implementation of a new organisational method in the company's business practices, workplace organisation or external relations.

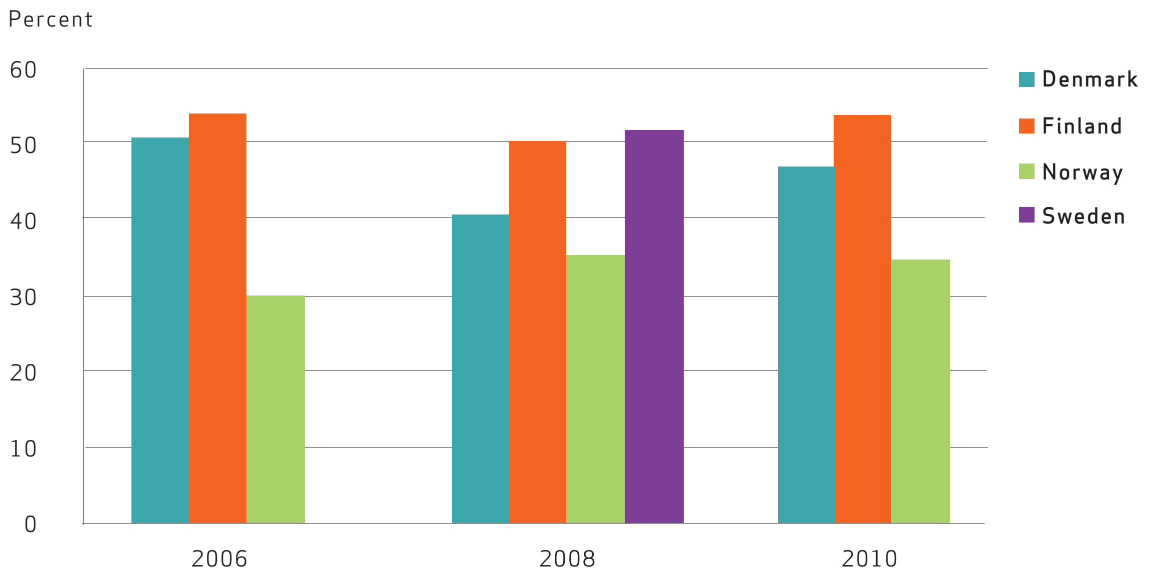
The first two types are traditionally more closely related to technological innovation (also referred to as TPP innovation). Companies are considered innovative if they have implemented an innovation during the period under review (the observation period is usually two to three years).

A.1 COMPANY INNOVATION BY COUNTRY

To illustrate the overall innovative performance of the Nordic countries, Figure A.1 compares the shares of innovative companies in the Nordic countries. In 2008 44 percent of the companies in the Nordic countries were innovative; Sweden had the highest share of innovative companies equalling to 52 percent, closely followed by Finland with 50 percent, 41 percent in Denmark and 36 percent in Norway.

In 2010, Finland had the highest share with 54 percent innovative companies, followed by Denmark with 47 percent. Norway had the smallest share with less than 35 percent of all companies introducing innovations. We cannot directly link this to the R&D investments. However, it is thus interesting to see the link between a lower level of R&D and a lower level of innovation.

Figure A.1 - Share of innovative companies, 2006-2010

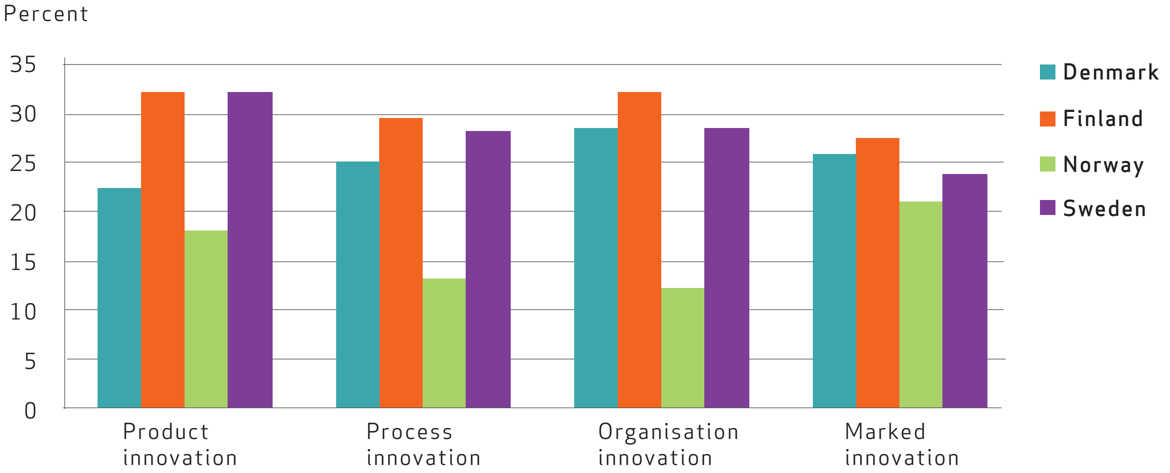


Note: 2008 data is the only innovation data available for Sweden.

Innovation can take various forms. The Oslo Manual identifies four different types of innovation, see Text Box 6.1. Figure A.2 shows how the Nordic Countries differ in share of innovative companies by different types of innovation. In Sweden and Finland the share of companies that introduce new products is higher than in Norway and Denmark. One third of the companies in Sweden and Finland introduce new products. In Denmark, it is 22 percent and in Norway, merely around 18 percent of the companies introduce new products. Sweden and Finland also have the highest R&D investments. Again, we cannot conclude whether there is a direct link, but it is obvious to think that developing new products potentially is a longer and more resource demanding process than the other types of innovation.

Danish companies seem to be relative more innovative when it comes to more soft types of innovation such as process and organisation innovation. Twenty-five percent of the Danish companies have introduced new processes and almost 30 percent have reorganised themselves. In Norway, the most common innovation is to change the way you approach the market. Just about 20 percent of the Norwegian companies have developed new marketing methods, new product designs or packaging etc.

Figure A.2 - Share of innovative companies by types of innovation in 2010



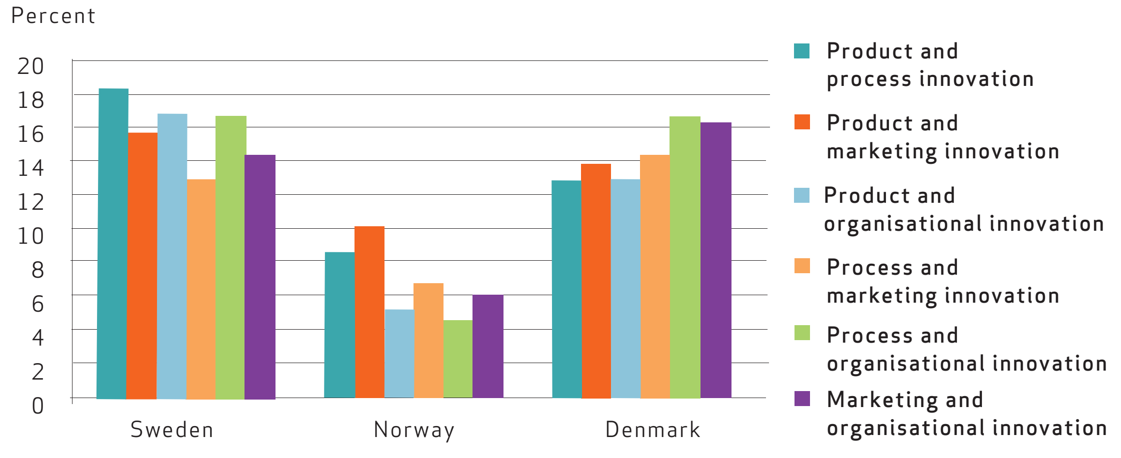
Note: 2010 data for Sweden is not available. 2008 data are used instead.

In general, product innovation is the most or second most common innovation type in Norway, Sweden and Finland. In contrast, product innovation is the least common innovation type in Denmark. This indicates a challenge for the Danish business sector, since it seems that R&D investments in the Danish business sector are not translated sufficiently into new innovative products in Danish companies compared to the product innovative activities in the companies in the other three Nordic countries.

Text Box A.2 - Different modes of innovation

Many companies are innovative in different ways and combine different types of innovations. This is partly because companies which introduce a new product on the market also choose to rethink the sales promotion of the product. In addition, to adjusting to new production methods companies that change the production process are also inclined to introduce changes in the organisation. That is also the case for Norway where most companies do product and marketing innovation at the same time, and in Denmark most companies do process and organisational innovation at the same time. Swedish innovative companies mostly combine product and process innovation.

Figure B.A.1 - Share of innovative companies by combination of innovation types in 2010



Note: 2010 data for Sweden is not available. 2008 data are used instead. Data is not available for Finland.

A.2 COMPANY INNOVATION BY INDUSTRY

As with business, for as far as R&D investments are concerned, it is useful to see how the Nordic countries compare to each other on a more disaggregate level with respect to innovation. Thus, this section describes the distribution of company innovation for selected industries in 2010.

Table A.1 compares the 10 industries with the largest share of innovative companies for each of the Nordic countries. The most innovative industries are also among the most knowledge intensive and R&D intensive ones. The industries typically lie within the high tech industry, KIBS or ICT. In Norway 80 percent of the companies in the industry Pharmaceuticals are innovative, while it is 71 percent in Denmark. Electronics is the industry in Denmark and Finland with the highest share of innovative companies. 75 and 80 percent of the companies are innovative, respectively. Mechanical engineering is the industry in Sweden with the most innovative companies with 69 percent.

Table A.1 - Top 10 industries with the largest share of innovative companies in 2010

RANKING	DENMARK		FINLAND		NORWAY		SWEDEN	
1	Electronics	75.4%	Electronics	80.1%	Pharmaceuticals	80.0%	Electronics	82.0%
2	Pharmaceuticals	70.5%	Chemicals	79.6%	Electronics	73.0%	Research and development (R&D)	70.5%
3	Manufacturing of electrical equipment	69.2%	Mechanical engineering	75.6%	Chemicals	59.8%	Mechanical engineering	68.9%
4	Mechanical engineering	64.7%	Manufacturing of electrical equipment	75.2%	Telecommunications	59.1%	Publishing, TV and radio	68.6%
5	Research and development (R&D)	62.0%	IT and information services	72.3%	Mechanical engineering	58.0%	IT and information services	68.2%
6	Publishing, TV and radio	61.6%	Financial and insurance activities	67.9%	IT and information services	57.3%	Telecommunications	67.4%
7	Telecommunications	59.8%	Telecommunications	66.7%	Research and development (R&D)	55.7%	Chemicals	66.1%
8	Chemicals	55.0%	Transport and transportation equipment	66.3%	Manufacturing of electrical equipment	53.8%	Manufacturing of electrical equipment	65.6%
9	Water and waste	51.6%	Pharmaceuticals	62.5%	Other business services	52.6%	Transport and transportation equipment	62.4%
10	IT and information services	50.9%	Plastics, gas and concrete	61.7%	Publishing, TV and radio	51.9%	Food, drink and tobacco	58.2%

Note: Sweden 2008. A full list of share of innovative companies by industry see appendix table A.1.6.

A.3 COMPANY INNOVATION BY COMPANY SIZE

It is expected that larger companies are more innovative. Table A.2 shows the share of innovative companies by full time employees for each country in 2010. It is evident that the size of the company has a positive effect on the company's probability of being innovative. Finland and Sweden have the highest shares of innovative companies in each category, closely followed by Denmark.

Norway has the lowest share of innovative companies in each category and in particular with their larger companies. In 2010, around 56 percent of the companies with more than 250 employees are innovative. In turn, 76 percent in Denmark, 80 percent in Finland and 84 percent in Sweden of the larger companies are innovative. Whether or not there is a link to the lower R&D investment among the larger companies in Norway is difficult to conclude. However, we see a convergence.

Table A.2 – Share of innovative companies in 2010 by company size

COMPANY SIZE	DENMARK	FINLAND	NORWAY	SWEDEN
2-49 employees	45%	51%	34%	47%
50-99 employees	54%	57%	42%	66%
100-250 employees	67%	69%	53%	69%
2-249 (SME) employees	45%	53%	35%	46%
More than 250 employees	76%	80%	56%	84%
Total	47%	54%	35%	52%

Note: 2010 data for Sweden is not available, 2008 data used instead.

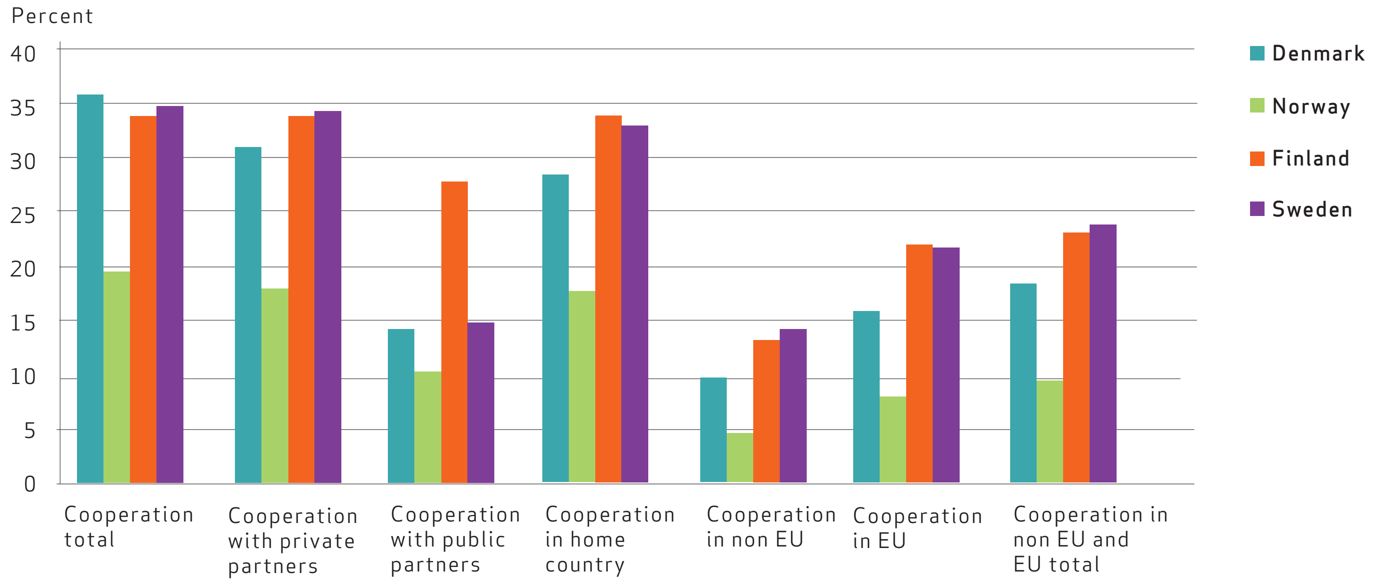
A.4 COLLABORATION ON INNOVATION

For companies, collaboration can be a valuable source to innovation related knowledge transfers. In particular, collaboration with public research organisations (higher education or government research institutions) can be an important source of knowledge transfer between science and industry.

Collaboration is embedded in the innovation process. According to Figure A.3 around 35 percent of the innovative companies in Denmark, Finland and Sweden collaborate on innovation activities, followed by Norway where almost 20 percent have innovation collaboration. Collaboration with suppliers, clients and customers dominates. Finland has a large share of companies that collaborates with both private and public partners, which is 34 and 28 percent, respectively. Collaboration is part of the innovation process regardless of companies performing R&D or not.

Collaboration with national partners dominates but collaboration with foreign partners can play an important role in the innovation process by allowing companies to gain access to a boarder pool of resources and knowledge at lower cost and to share the risks. Among Finnish and Swedish innovative companies, non-European collaborations are the predominant form of cross-country co-operation on innovation, while it is intra-European collaboration for Danish and Norweign companies.

Figure A.3 - Share of innovative companies with innovation collaboration in 2010



Note: 2010 data for Sweden is not available. 2008 data are used instead.

Table A.3 shows that whereas around one third of the innovative small size companies collaborates the share increases to around 60 percent for companies with more than 250 employees. In Finland, even 70 percent of the innovative companies with more than 250 employees collaborate with other on their innovation. Again we see that Norway is falling behind. The lower share in Norway might be a mirror of the lower share of innovative companies, it is thus more difficult in Norway for companies to find a sound collaboration partner.

It is evident that the size of the companies has a positive effect on the company's probability of collaboration on innovation. The large companies can have a higher possibility to incorporate external knowledge in its innovation processes because they have the capacity in R&D resources but also human resources.

Table A.3 – Share of innovative companies with innovation collaboration in 2010 by size of company

COMPANY SIZE	DENMARK	FINLAND	NORWAY	SWEDEN
2-49 employees	33%	29%	17%	32%
50-99 employees	34%	38%	24%	33%
100-250 employees	40%	51%	33%	47%
2-249 (SME) employees	33%	32%	18%	33%
More than 250 employees	57%	70%	48%	62%
Total	34%	34%	19%	35%

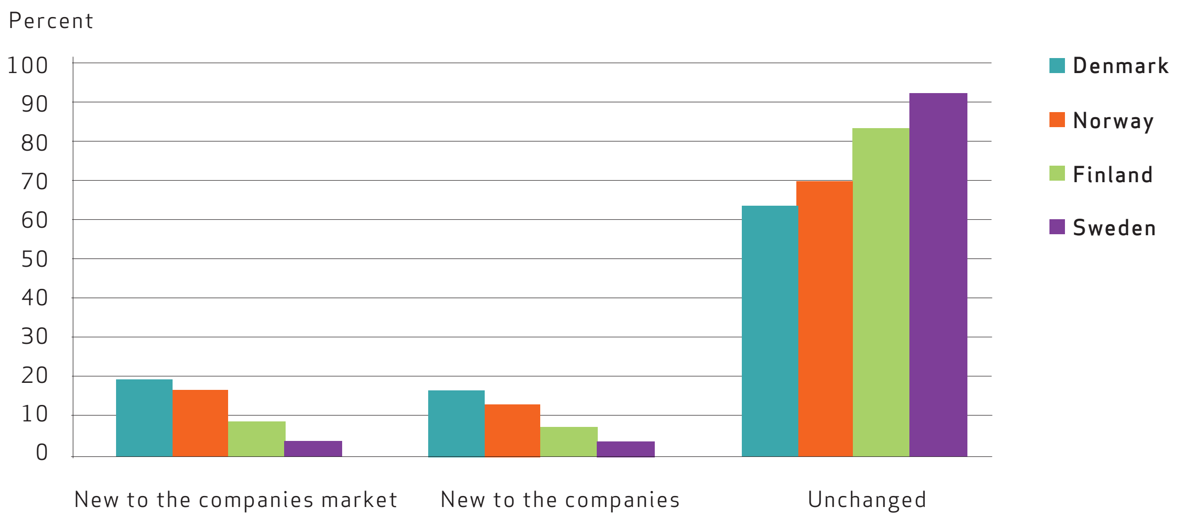
Note: 2010 data for Sweden is not available, 2008 data used instead.

A.5 REVENUE FROM NEW INNOVATIONS

One of the main incentives which motivate companies to be innovative is the expectation that innovations increase the companies' revenue. It is therefore of interest to see how innovations affect company revenue in the Nordic countries.

Figure A.4 show the share of the company revenues that can be attributed to innovations for each of the Nordic countries. In 2010 between 11 and 36 percent of the company revenues, in the Nordic countries came from innovations that were new to the companies' market or to the companies. Sweden and Finland that are the most innovative countries, but shares of 64 and 93 percent of the company revenues are unaffected by innovations. Denmark and Norway perform slightly better, whereas it is 64 and 70 percent of companies' revenue that are not affected by innovations. This is also reflected in the rate of return of business R&D investment. Denmark experiences the largest rate of return, Norway and Finland have the same rate of return and Sweden has the lowest rate of return. This suggests that Finnish and especially Swedish companies have more difficulties in converting innovations into increased revenue, compared to Denmark and Norway.

Figure A.4 - Share of revenue from innovations in 2010



Note: 2010 data for Sweden is not available. 2008 data are used instead.

APPENDIX B - EDUCATIONAL LEVEL IN THE NORDIC COUNTRIES

The educational level of the workforce is an important factor in transferring R&D investments into value to a market. That includes the effectiveness of which companies implement new technologies and innovations, coming from R&D efforts, in the daily production. The share of highly educated people in relation to the total staff in a company is also important for the labour productivity impact of R&D and innovation investments in the company. The Danish Agency for Science, Technology and Innovation (2011) and Junge et al. (2012) have shown that the productivity impact of research collaboration and innovation is positively correlated with the share of highly educated people in the workforce.

B.1 THE LEVEL OF EDUCATION IN COMPANIES BY COUNTRY

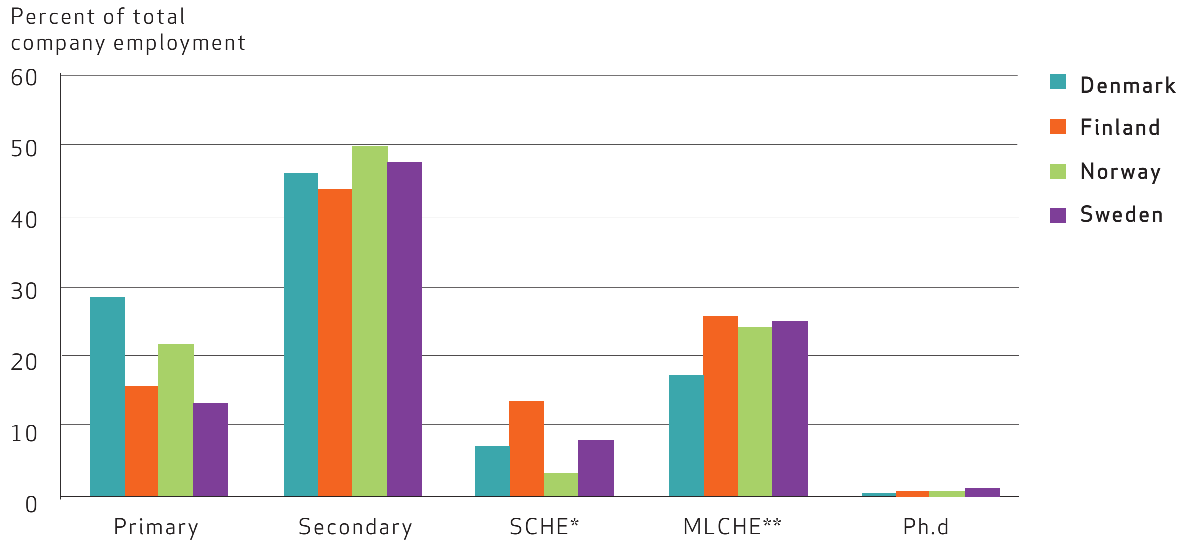
Figure B.1 shows the composition of employees by level of education in 2010 for Denmark, Finland, Norway and Sweden. The following five categories of educational levels are represented in the figure: primary, secondary, short cycle higher education, medium and long cycle higher education and PhD-education:

1. Employees with a Ph.D.-education represent around one percent of the total employment in the Nordic countries.
2. The share of employees with a medium and long cycle higher education constitutes around 25 percent in Sweden, Norway and Finland and 17 percent in Denmark.
3. In Finland 14 percent of the employees have a short cycle higher education, in Denmark Norway and Sweden between three and eight percent of the employees that have a short cycle education.
4. Finland and Norway have the lowest and highest share of employees respectively with a secondary education of 44 and 50 percent. Denmark and Sweden have a share of 47 and 48 percent respectively.
5. Denmark has the highest share of employees with a primary education of 31 percent. Norway, Finland and Sweden have a share of 22, 16 and 13 percent.

Overall Sweden and Finland have the lowest shares of employees with a primary education and the highest shares of employees with a medium and long cycle higher education and a PhD-education in the workforce of the business sector.

Compared to the other countries, Denmark has a larger share of employees with a primary or secondary education, and correspondingly a lower share of employees in companies with a short, medium or long cycle higher education or Ph.d compared.

Figure B.1 – Composition of employees in innovative companies in 2010 by level of education



Note: 2010 data for Sweden is not available. 2009 data used instead.
Percent of total full time employee in innovative companies.
*: Short cycle higher education
**: Medium and long cycle higher education

B.2 THE LEVEL OF EDUCATION IN COMPANIES BY INDUSTRY

Table B.1 shows the composition of employees by level of education across industries in the four Nordic countries. In the table, the composition of educational level is expressed in terms of percent of employment within each private sector. The table clearly shows that the composition varies significantly across industries. Although there are some differences the variations across the four Nordic countries are minor. The interested reader should take a closer look at table B.1.

The general picture, which can be derived from Table B.1, is that the shares of the workforce in the private sector with a

Table B.1 Educational composition of employees in innovative companies in 2010 by industry (percent)

Percent		DENMARK					FINLAND				
Industry code	Industry	Primary	Second-ary	SCHE*	MLCHE**	Ph.d	Primary	Second-ary	SCHE*	MLCHE**	Ph.d
A	Agriculture, forestry and fishing	41.1 %	36.7 %	10.1 %	11.7 %	0.3 %	...	...	...	...	...
B	Natural resource extraction	27.5 %	50.7 %	7.8 %	13.6 %	0.3 %	21.1 %	54.1 %	10.6 %	13.2 %	0.9 %
CA	Food, drink and tobacco	41.2 %	43.7 %	7.0 %	7.9 %	0.1 %	22.3 %	56.6 %	9.9 %	11.0 %	0.1 %
CB	Textiles and leather	38.5 %	44.9 %	7.7 %	9.0 %	...	22.7 %	54.8 %	10.4 %	12.1 %	N/A %
CC	Wood, paper and printing	33.6 %	55.9 %	4.3 %	6.2 %	...	18.1 %	53.6 %	12.0 %	16.0 %	0.2 %
CD	Oil refineries, etc.	...	...	...	...	...	...	...	...	...	...
CE	Chemicals	19.7 %	38.5 %	15.3 %	23.4 %	3.2 %	14.0 %	43.5 %	14.1 %	26.2 %	2.2 %
CF	Pharmaceuticals	11.2 %	28.3 %	17.3 %	37.8 %	5.4 %	12.1 %	37.2 %	12.0 %	33.2 %	5.5 %
CG	Plastics, gas and concrete	38.0 %	45.0 %	5.9 %	10.8 %	0.3 %	22.1 %	51.0 %	12.6 %	14.1 %	0.2 %
CH	Metals	32.3 %	54.3 %	5.8 %	7.5 %	0.1 %	17.8 %	56.6 %	10.1 %	15.3 %	0.2 %
CI	Electronics	22.6 %	37.1 %	10.5 %	28.3 %	1.4 %	9.9 %	23.0 %	10.1 %	54.9 %	2.1 %
CJ	Manufacturing of electrical equipment	26.5 %	46.0 %	11.4 %	16.0 %	...	13.3 %	43.5 %	11.4 %	31.1 %	0.7 %
CK	Mechanical engineering	22.3 %	51.3 %	8.6 %	...	0.3 %	11.5 %	45.3 %	11.0 %	31.7 %	0.5 %
CL	Transport and transportation equipment	30.1%	55.3 %	6.0 %	8.5 %	0.1 %	16.4 %	58.5 %	8.7 %	16.1 %	0.3 %
CM	Other manufacturing	27.6 %	54.0 %	6.2 %	12.1 %	0.1 %	20.6 %	56.0 %	11.6 %	11.8 %	...
D	Energy	12.1 %	39.5 %	8.7 %	38.7 %	1.0 %	9.2 %	40.2 %	21.1 %	29.1 %	0.5 %
E	Water and waste	40.7 %	45.4 %	4.4 %	9.5 %	...	24.3 %	47.3 %	13.9	13.9 %	0.5 %
F	Construction	25.1 %	58.5 %	6.4 %	10.0 %	0.0 %	...	...	...	...	...
G	Wholesale and retail trade	36.5 %	49.3 %	5.7 %	8.4 %	0.1 %	16.8 %	41.5 %	19.5 %	21.9 %	0.3 %
H	Transportation and storage	35.9 %	51.0 %	4.2 %	8.8 %	0.0 %	28.2 %	53.9 %	8.8 %	9.1 %	0.1 %
I	Accommodation and food service activities	50.8 %	41.6 %	3.0 %	4.7 %	...	...	...	...	...	...
JA	Publishing, TV and radio	27.4 %	34.9 %	5.8 %	31.5 %	0.4 %	11.4 %	36.8 %	15.2 %	35.9 %	0.8 %
JB	Telecommunications	18.8 %	55.4 %	7.3 %	18.2 %	0.2 %	7.5 %	32.2 %	21.8 %	38.2 %	0.3 %
JC	IT and information services	10.6 %	36.9 %	11.8 %	39.8 %	0.9 %	5.5 %	24.1 %	15.8 %	53.6 %	1.0 %
K	Financial and insurance activities	9.3 %	56.5 %	11.1 %	22.9 %	0.2 %	8.7 %	25.5 %	29.9 %	35.6 %	0.4 %
L	Real estate activities	32.0 %	46.3 %	8.5 %	13.2 %	...	...	...	...	...	...
MA	Consultancy and advisory services	9.3 %	27.7 %	8.1 %	53.9 %	1.1 %	4.5 %	19.5 %	12.7 %	61.7 %	1.5 %
MB	Research and development (R&D)	10.8 %	24.4 %	12.0 %	46.3 %	6.5 %	...	...	...	...	...
MC	Other business services	16.0 %	42.6 %	9.9 %	31.0 %	0.6 %	...	...	...	...	...
N	Administrative and support service activities	42.0 %	44.5 %	4.4 %	9.1 %	...	...	...	...	...	...
Average		28,6 %	46,6 %	7,1 %	17,2 %	0,4 %	15,9 %	44,0 %	14,0 %	25,5 %	0,6 %

Note: 2010 data for Sweden is not available. 2009 data used instead.

Percent of total full time employee in innovative companies.

*: Short cycle higher education

**: Medium and long cycle higher education medium and longer cycle higher education and a Ph.D.-education are higher in high-tech and knowledge intensive industries. These are also the industries with highest levels of R&D investments and the most innovative industry sectors.

In general the share of the workforce with short cycle higher education or no higher education is higher in agriculture, forestry, fishing, water, waste and natural resource extraction and low-tech industries such as food, drink, textile, wood, paper, printing etc. and many service industries such as transportation, construction, real estate activities, administrative and support service activities. In all Nordic countries the level of R&D spending is in general very low in these sectors.

Percent		NORWAY					SWEDEN				
Industry code	Industry	Primary	Secondary	SCHE*	MLCHE**	Ph.d	Primary	Secondary	SCHE*	MLCHE**	Ph.d
A	Agriculture, forestry and fishing	...	...	...	...	...	16.7 %	44.8 %	4.7 %	32.4 %	1.5 %
B	Natural resource extraction	32.9 %	54.3 %	1.1 %	11.4 %	0.3 %	13.1 %	67.4 %	6.2 %	12.6 %	0.7 %
CA	Food, drink and tobacco	23.4 %	49.3 %	2.1 %	24.0 %	1.2 %	22.7 %	58.7 %	5.9 %	12.4 %	0.2 %
CB	Textiles and leather	35.5 %	51.4 %	1.2 %	11.9 %	-	28.8 %	53.3 %	7.7 %	9.7 %	0.4 %
CC	Wood, paper and printing	27.8 %	61.4 %	1.6 %	9.1 %	0.1 %	22.5 %	58.2 %	7.2 %	11.8 %	0.3 %
CD	Oil refineries, etc.	...	...	...	...	...	...	...	...	...	...
CE	Chemicals	19.2 %	52.3 %	3.6 %	22.7 %	2.1 %	13.2 %	45.4 %	10.3 %	27.6 %	3.5 %
CF	Pharmaceuticals	16.5 %	41.2 %	4.3 %	34.1 %	3.9 %	...	...	...	...	...
CG	Plastics, gas and concrete	32.6 %	54.3 %	2.0 %	11.0 %	0.1 %	25.5 %	58.1 %	5.8 %	10.3 %	0.2 %
CH	Metals	25.0 %	58.6 %	2.7 %	13.2 %	0.5 %	18.8 %	60.7 %	6.9 %	13.1 %	0.6 %
CI	Electronics	13.3 %	41.0 %	6.7 %	37.5 %	1.6 %	...	...	...	...	...
CJ	Manufacturing of electrical equipment	25.9 %	52.8 %	3.6 %	17.3 %	0.4 %	14.6 %	50.5 %	10.3 %	23.1 %	1.4 %
CK	Mechanical engineering	18.2 %	54.7 %	3.9 %	22.9 %	0.4 %	13.7 %	55.7 %	9.7 %	20.4 %	0.6 %
CL	Transport and transportation equipment	17.3 %	57.0 %	3.3 %	22.0 %	0.3 %	13.9 %	52.5 %	9.2 %	23.4 %	1.1 %
CM	Other manufacturing	23.6 %	58.4 %	2.2 %	15.6 %	0.2 %	16.5 %	51.7 %	8.0 %	22.6 %	1.2 %
D	Energy	...	...	...	...	...	8.3 %	40.2 %	13.9 %	36.4 %	1.1 %
E	Water and waste	40.5 %	51.4 %	1.3 %	6.5 %	0.3 %	22.4 %	53.1 %	6.5 %	17.4 %	0.6 %
F	Construction	25.4 %	63.1 %	2.1 %	9.3 %	0.0 %	16.9 %	64.4 %	7.0 %	11.5 %	0.1 %
G	Wholesale and retail trade	23.6 %	54.6 %	3.0 %	18.7 %	0.2 %	16.2 %	57.7 %	7.6 %	18.1 %	0.3 %
H	Transportation and storage	27.1 %	57.6 %	2.0 %	13.3 %	0.1 %	16.4 %	57.2 %	7.3 %	19.0 %	0.2 %
I	Accommodation and food service activities	39.9 %	43.9 %	0.7 %	15.3 %	0.1 %	22.7 %	59.7 %	5.4 %	12.3 %	0.0 %
JA	Publishing, TV and radio	10.4 %	33.2 %	7.6 %	48.2 %	0.5 %	6.6 %	31.5 %	11.5 %	49.3 %	1.1 %
JB	Telecommunications	12.1 %	39.6 %	6.1 %	41.6 %	0.6 %	...	...	...	...	...
JC	IT and information services	8.3 %	29.0 %	7.0 %	55.0 %	0.7 %	3.0 %	27.2 %	14.5 %	54.5 %	0.9 %
K	Financial and insurance activities	...	...	...	...	...	...	...	...	...	...
L	Real estate activities	...	...	...	...	...	19.5 %	51.4 %	7.2 %	22.0 %	0.0 %
MA	Consultancy and advisory services	7.7 %	27.4 %	5.8 %	57.4 %	1.7 %	4.2 %	27.6 %	11.6 %	53.8 %	2.8 %
MB	Research and development (R&D)	6.0 %	15.7 %	3.5 %	61.0 %	13.8 %	...	...	...	...	...
MC	Other business services	12.0 %	29.7 %	3.3 %	51.9 %	3.1 %	8.4 %	41.1 %	12.0 %	37.8 %	0.7 %
N	Administrative and support service activities	14.2 %	49.0 %	3.5 %	32.5 %	0.8 %	13.0 %	55.6 %	8.2 %	23.0 %	0.2 %
Average		21,9 %	50,4 %	3,2 %	24,1 %	0,5 %	13,3 %	47,9 %	8,1 %	24,9 %	1,0 %

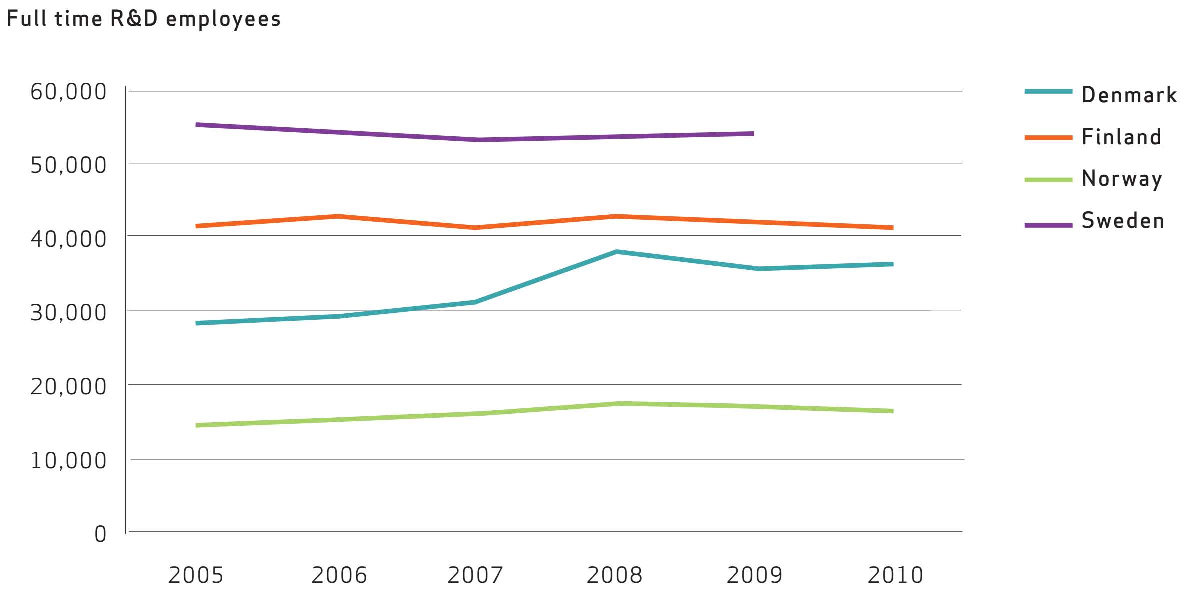
B.3 HUMAN RESOURCES IN R&D

Together with business R&D investments, human resources in R&D constitute another key indicator of a country's R&D efforts. Until now Appendix B has described the composition of education in the various business sectors in the Nordic countries.

Here we focus on R&D-personnel in the business sector. Figure B.2 shows the number of R&D employees in the Nordic countries from 2005 to 2010. In 2009, approximately 150,000 people participated in R&D in the Nordic countries, which translates into six persons per 1,000 inhabitants. In 2009, Sweden's share was 36 percent corresponding to 54,000 R&D employees, while Finland's share was 28 percent, Denmark's share was 24 percent and Norway's share was 11 percent. The number of R&D employees in the Nordic countries exhibits the same trend as for companies R&D expenditure.

In Denmark the number of R&D employees increased sharply and increased in Norway from 2005 to 2010. In both Sweden and Finland the number of R&D employees decrease. Over a period of five years from 2005 to 2010, Denmark increased the number of R&D employees from 28,359 to 36,324. It is an average annual growth of 5.6 percent. Norway had an average annual growth rate of 2.9 percent, which translate in to an increase from 15,283 R&D employees in 2005 to 16,507 R&D employees in 2010. Both Finland and Sweden had a negative average annual growth rate of -0.1 and -0.6 percent, translating into a decrease in R&D employees from 54,188 and 42,665 in 2005 to 53,841 in 2009 and 41,250 in 2010, respectively.

Figure B.2 - Number of R&D employees in companies, 2005-2010

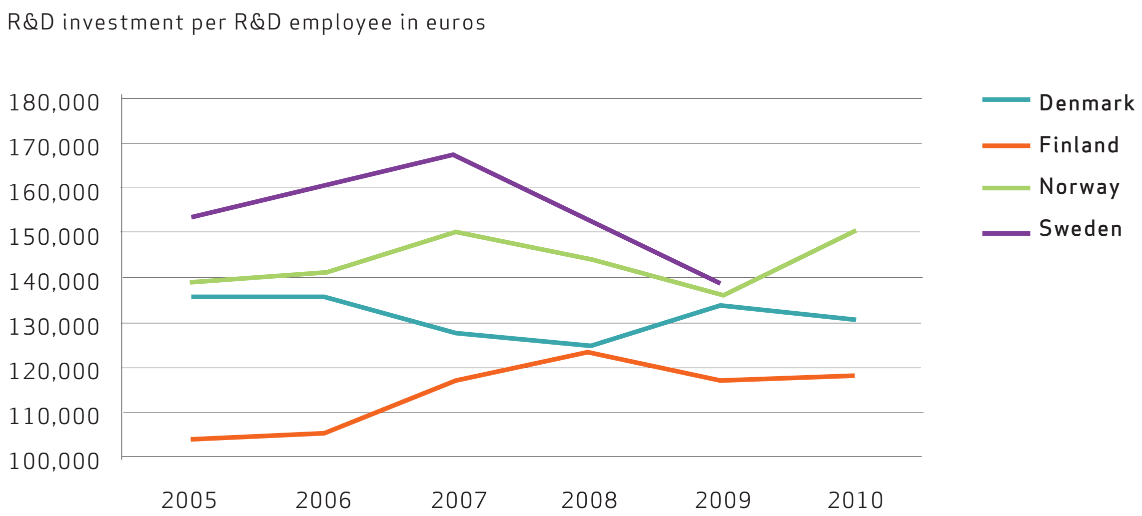


Note: Data for Sweden is only available in uneven years. Data in even years are interpolated (an average on the two nearby years).
R&D employees are full time equivalent (FTE).

Figure B.3 shows R&D intensity calculated as R&D expenditure per R&D employee. When looking at how much an R&D employee cost, Norway outperforms Denmark and Finland in the period. Among the four Nordic countries Sweden still has the highest R&D costs per R&D employee. It seems possible, however, that Norway surpasses Sweden in 2010. From 2007 to 2009, Sweden experienced a decrease in its R&D costs per R&D employee, which could be explained by a decrease in the business R&D investments more than a decrease in the number of R&D employees.

The cost of an R&D employee varies in the four Nordic countries. The cost of R&D employees can be calculated as the investment in R&D per R&D employees. We see, however, some variation. There appears to be a convergence from 2005 and forward. In 2005, an R&D employee costs around 153,000 euros in Sweden and around 104,000 euros in Finland, a difference of almost 50 percent. In 2009, the difference between the two countries has diminished to less than 20 percent.

Figure B.3 – Cost of R&D employee, 2005-2010



Note: Data for Sweden is only available in uneven years. Data in even years is interpolated (an average on the two nearby years).
R&D employees are full time equivalent (FTE).

APPENDIX C - DESCRIPTIVE STATISTICE

C.1 DESCRIPTIVE STATISTICS

The following four tables present the descriptive statistics describing the fundamental data of the study.

Table C.1.1 – Denmark descriptive statistics

DENMARK	# OBS.	MEAN	MEDIAN	10TH PERCENTILE	90TH PERCENTILE
Value added*	5,744	26,160	6,729	826	48,010
Physical capital*	5,744	44,697	3,515	165	53,828
R&D capital*	5,744	13,606	1,019	86	13,504
Full time employee (FTE)	5,744	253	82	10	494
Value added per FTE*	5,744	88	79	52	129
Value added per R&D capital	5,744	70,6	5,4	0,6	66,8
R&D capital per FTE*	5,744	62	15	1	139
Capital per FTE*	5,744	97	44	7	198
Investments in R&D*	4,273	3,352	110	0	2,978
Investments in R&D (imputed)*	5,744	2,605	85	0	2,111

*: 1,000 euro, 2010 prices

Table C.1.2 – Norway descriptive statistics

NORWAY	# OBS.	MEAN	MEDIAN	10TH PERCENTILE	90TH PERCENTILE
Value added*	4,584	19,255	5,058	1,183	33,239
Physical capital*	4,584	33,105	2,063	202	34,235
R&D capital*	4,584	6,535	1,684	333	9,800
Full time employee (FTE)	4,584	148	53	11	285
Value added per FTE*	4,584	106	94	53	163
Value added per R&D capital	4,584	14,8	2,9	0,5	24,2
R&D capital per FTE*	4,584	71	32	4	174
Capital per FTE*	4,584	110	37	7	204
Investments in R&D*	3,935	1,448	358	0	2,455
Investments in R&D (imputed)*	4,584	1,283	321	0	2,097

*: 1,000 euro, 2010 prices

Table C.1.3 – Finland descriptive statistics

FINLAND	# OBS.	MEAN	MEDIAN	10TH PERCENTILE	90TH PERCENTILE
Value added*	6,440	23,025	3,317	325	35,263
Physical capital*	6,440	67,289	1,599	57	50,192
R&D capital*	6,440	17,643	1,284	219	11,548
Full time employee (FTE)	6,440	209	43	2	378
Value added per FTE*	6,440	82	64	37	123
Value added per R&D capital	6,440	7.6	2.3	0.3	15.5
R&D capital per FTE*	6,440	71	30	5	173
Capital per FTE*	6,440	193	35	4	191
Investments in R&D*	4,759	3,390	253	0	2,409
Investments in R&D (imputed)*	6,440	3,028	218	0	2,113

*: 1,000 euro, 2010 prices

Table C.1.4 – Sweden descriptive statistics

SWEDEN	# OBS.	MEAN	MEDIAN	10TH PERCENTILE	90TH PERCENTILE
Value added*	4,048	57,379	12,697	1,646	109,807
Physical capital*	4,048	188,126	8,708	401	172,889
R&D capital*	4,048	37,777	4,510	254	45,447
Full time employee (FTE)	4,048	430	143	18	834
Value added per FTE*	4,048	113	83	49	162
Value added per R&D capital	4,048	37.8	2.9	0.4	35.1
R&D capital per FTE*	4,048	89	28	3	211
Capital per FTE*	4,048	303	54	9	352
Investments in R&D*	1,992	8,180	524	0	8,074
Investments in R&D (imputed)*	4,048	7,124	442	0	7,144

*: 1,000 euro, 2010 prices, All the R&D investments are imputed in equal years

Table C.1.5. Business R&D investments by industry

Million DKK 2010-prices		DENMARK	NORWAY	FINLAND	SWEDEN
Industry code	Industry	2010	2010	2010	2009
A	Agriculture, forestry and fishing	53	N/A	26	107
B	Natural resource extraction	44	219	61	130
CA	Food, drink and tobacco	378	1,640	434	265
CB	Textiles and leather	31	63	37	59
CC	Wood, paper and printing	48	132	875	566
CD	Oil refineries, etc.	...	...	...	...
CE	Chemicals	1,579	893	924	1,222
CF	Pharmaceuticals	7,063	459	790	...
CG	Plastics, gas and concrete	429	238	468	204
CH	Metals	121	976	787	1,397
CI	Electronics	2,537	1,189	19,272	...
CJ	Manufacturing of electrical equipment	534	306	1,737	710
CK	Mechanical engineering	4,709	622	2,597	3,760
CL	Transport and transportation equipment	118	545	354	10,537
CM	Other manufacturing	983	418	227	1,378
D	Energy	231	N/A	155	72
E	Water and waste	7	7	155	11
F	Construction	56	122	435	122
G	Wholesale and retail trade	1,336	625	562	1,728
H	Transportation and storage	147	130	78	93
I	Accommodation and food service activities	4	8	5	N/A
JA	Publishing, TV and radio	867	1,643	401	535
JB	Telecommunications	242	783	328	...
JC	IT and information services	4,732	2,603	2,356	2,015
K	Financial and insurance activities	3,872	776	511	...
L	Real estate activities	...	N/A	18	8
MA	Consultancy and advisory services	1,027	2,307	967	3,781
MB	Research and development (R&D)	4,080	925	849	...
MC	Other business services	121	345	94	30
N	Administrative and support service activities	59	162	24	25
Total		35,413	18,525	36,408	55,789

It should be noted that the total amount of R&D investments does not add up to the sum of the individual industries in table A.1.5 due to discretioniced data in some industries.

Table C.1.6. Share of enterprises with innovation in 2010 by industry

Percent		DENMARK	NORWAY	FINLAND	SWEDEN
Industry code	Industry	2010	2010	2010	2009
A	Agriculture, forestry and fishing	N/A	N/A	...	N/A
B	Natural resource extraction	29.0 %	24.8 %	29.9 %	26.7 %
CA	Food, drink and tobacco	36.9 %	53.6 %	36.3 %	58.2 %
CB	Textiles and leather	47.1 %	42.8 %	44.3 %	50.6 %
CC	Wood, paper and printing	48.9 %	47.1 %	39.8 %	49.6 %
CD	Oil refineries, etc.	...	...	...	...
CE	Chemicals	55.0 %	79.6 %	59.8 %	66.1 %
CF	Pharmaceuticals	70.5 %	62.5 %	80.0 %	...
CG	Plastics, gas and concrete	50.9 %	61.7 %	44.0 %	57.5 %
CH	Metals	43.0 %	54.7 %	28.8 %	45.6 %
CI	Electronics	75.4 %	80.1 %	73.0 %	82.0 %
CJ	Manufacturing of electrical equipment	69.2 %	75.2 %	53.8 %	65.6 %
CK	Mechanical engineering	64.7 %	75.6 %	58.0 %	68.9 %
CL	Transport and transportation equipment	38.5 %	66.3 %	43.6 %	62.4 %
CM	Other manufacturing	46.5 %	45.8 %	36.2 %	52.2 %
D	Energy	49.1 %	48.0 %	...	54.2 %
E	Water and waste	51.6 %	44.5 %	32.9 %	42.4 %
F	Construction	39.4 %	N/A	21.9 %	...
G	Wholesale and retail trade	45.6 %	59.3 %	34.8 %	53.3 %
H	Transportation and storage	49.5 %	31.1 %	21.3 %	27.6 %
I	Accommodation and food service activities	37.6 %	N/A	24.2 %	N/A
JA	Publishing, TV and radio	61.6 %	54.5 %	51.9 %	68.6 %
JB	Telecommunications	59.8	66.7 %	59.1 %	67.4 %
JC	IT and information services	50.9 %	72.3 %	57.3 %	68.2 %
K	Financial and insurance activities	48.9 %	67.9 %	40.9 %	44.3 %
L	Real estate activities	40.1 %	N/A	...	N/A
MA	Consultancy and advisory services	43.6 %	50.0 %	36.2 %	53.9 %
MB	Research and development (R&D)	62.0 %	N/A	55.7 %	70.5 %
MC	Other business services	45.7 %	N/A	52.6 %	N/A
N	Administrative and support service activities	36.5 %	N/A	33.7 %	N/A
Total		47.2 %	53.7 %	36.2 %	51.9 %

C.2 ADJUSTING THE BASELINE MODEL FOR THE QUALITY OF LABOUR FORCE

As mentioned in Section 3.1.3, a high-educated labour force tends to be more productive than a low-educated labour force. Hence, it is important to adjust for the quality of the labour force in order to avoid an overestimation of the R&D elasticities. The effects of adjusting the baseline model with respect to the quality of labour by using the labour index instead of FTE are shown in Table C.2.1.

The correction of the quality of the labour lowers the size of the R&D elasticities. This suggests that by using FTE as proxy for labour force, we overestimate the effect of R&D on labour productivity. The labour force elasticity is estimated as negative and significant for Denmark, suggesting a non-optimal allocation of the input factors for Denmark as well. Overall, the results from Table 4.1 are not strongly affected by the correction of the quality of the labour force.

Table C.2.1 - Labour force quality corrected baseline model

SECTOR	DENMARK	NORWAY	FINLAND	SWEDEN
Log (R&D capital/Labour index)	0.068***	0.11***	0.144***	0.098***
Log (Physical capital/Labour index)	0.139***	0.133***	0.143***	0.220***
Log(Labour index)	-0.023***	0.000	-0.012**	-0.061***
Constant	10.118***	10.141***	8.242***	9.425***
Export intensity	Yes	Yes	No	Yes
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
R-sq.	0.422	0.312	0.2845	0.4288
N	5,712	4,584	6,440	4,048

Notes: ***,** and * indicate significance at the 1, 5 and 10 percent level.

The weights to adjust for the quality of labor are displayed in Table A.2.2.

Table C.2.2 - Labour force quality correcting weights

COUNTRY	PRIMARY	SECONDARY	SCHE*	MLCHE**	PH.D
Denmark	1.00	1.58	1.84	2.56	3.18
Norway	1.00	1.21	1.42	1.78	1.78
Finland	1.00	1.02	1.31	1.68	2.44
Sweden	1.00	1.05	1.25	1.44	1.95

C.3 FULL MODELS BY SECTOR AND COMPANY SIZE

In chapter 4.2 there are references to the full scale model in calculating the R&D elasticities. The results are presented in the tables below.

Table C.3.1 – Industry performance in Denmark

SECTOR	HIGH TECH INDUSTRY	MEDIUM AND LOW TECH INDUSTRY	ICT	BUSINESS SERVICE	OTHER SERVICE	OTHER	TOTAL
Log (R&D capital/FTE)	0.09***	0.032***	0.147***	0.120***	0.075***	-0.007	0.091***
Log (Physical capital/FTE)	0.123***	0.17***	0.134***	0.118***	0.071***	0.069***	0.132***
Log(FTE)	0.009	0.041***	0.000	-0.005	-0.001	0.006	-0.002
Constant	10.463***	10.322***	9.962***	10.525***	11.663***	12.334***	10.097***
Export intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	No	No	No	No	No	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-sq.	0.290	0.228	0.350	0.398	0.240	0.219	0.322
N	1,609	1,445	865	875	819	131	5,744

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.2 – Sector performance in Norway

SECTOR	HIGH TECH INDUSTRY	MEDIUM AND LOW TECH INDUSTRY	ICT	BUSINESS SERVICE	OTHER SERVICE	OTHER	TOTAL
Log (R&D capital/FTE)	0.111***	0.075***	0.164***	0.17***	0.153***	0.063***	0.128***
Log (Physical capital/FTE)	0.169***	0.111***	0.128***	0.13***	0.108***	0.136***	0.132***
Log(FTE)	0.026	0.038***	-0.013	-0.015	-0.034	-0.007	0.0056
Constant	9.795***	10.867***	10.178***	10.083***	10.466***	10.141***	10.05***
Export intensity	Yes	Yes	No	Yes	Yes	Yes	Yes
Industry dummies	No	No	No	No	No	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-sq.	0.309	0.156	0.377	0.510	0.254	0.334	0.401
N	930	1,741	908	452	364	189	4,584

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.3 – Industry performance in Finland

SECTOR	HIGH TECH INDUSTRY	OTHER INDUSTRY	ICT	BUSINESS SERVICE	OTHER	OTHER	TOTAL
service	Other	Total	0.147***	0.120***	0.075***	-0.007	0.091***
Log (R&D capital/FTE)	0.206***	0.084***	0.241***	0.215***	0.106***	0.086**	0.167***
Log (Physical capital/FTE)	0.115***	0.239***	0.065***	0.082***	0.088***	0.273***	0.142***
Log(FTE)	-0.012	-0.019***	0.025	-0.001	-0.038**	0.119***	-0.008*
Constant	7.850***	7.638***	8.081***	8.248***	9.472***	6.890***	8.119***
Export intensity	No	No	No	No	No	No	No
Industry dummies	No	No	No	No	No	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-sq.	0.353	0.397	0.299	0.382	0.171	0.288	0.345
N	1,938	2,217	1,005	707	370	203	6,440

Notes: FTE = full time equivalent. Export data is not available for Finland
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.4 – Industry performance in Sweden

SECTOR	HIGH TECH INDUSTRY	OTHER INDUSTRY	ICT	BUSINESS SERVICE	OTHER	OTHER	TOTAL
service	Other	Total	0.164***	0.17***	0.153***	0.063***	0.128***
Log (R&D capital/FTE)	0.103***	0.020**	0.210***	0.257***	0.079***	0.125***	0.107***
Log (Physical capital/FTE)	0.156***	0.361***	0.095***	0.097***	0.149***	0.128***	0.226***
Log(FTE)	-0.016*	-0.055***	0.036	-0.062***	-0.219***	0.000***	-0.067***
Constant	9.983***	8.416***	9.629***	9.479***	11.871***	10.284***	9.410***
Export intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	No	No	No	No	No	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-sq.	0,300	0,538	0,487	0,682	0,512	0,337	0,461
N	1,536	1,366	283	396	250	217	4,048

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.5 - Company size in Denmark

SECTOR	2-49	50-99	100-250	250+	TOTAL
Log (R&D capital/FTE)	0.106***	0.043***	0.064***	0.095***	0.091***
Log (Physical capital/FTE)	0.139***	0.095***	0.092***	0.117***	0.132***
Log(FTE)	-0.097***	-0.238***	-0.176***	0.030**	-0.002
Constant	11.075***	12.696***	11.879***	10.184***	10.097***
Export Intensity	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.431	0.189	0.249	0.347	0.322
N	2,001	1,101	1,382	1,260	5,744

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.6 - Company size in Norway

SECTOR	2-49	50-99	100-250	250+	TOTAL
Log (R&D capital/FTE)	0.175***	0.093***	0.051***	0.101***	0.128***
Log (Physical capital/FTE)	0.098***	0.103***	0.174***	0.169***	0.132***
Log(FTE)	-0.114***	0.148**	-0.11*	0.025	0.0056
Constant	10.237***	10.237***	11.044***	9.924***	10.05***
Export Intensity	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.485	0.366	0.373	0.416	0.401
N	2,173	1,087	807	517	4,584

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.7 - Company size in Finland

SECTOR	2-49	50-99	100-250	250+	TOTAL
Log (R&D capital/FTE)	0.219***	0.090***	0.091***	0.142***	0.167***
Log (Physical capital/FTE)	0.100***	0.166***	0.166***	0.145***	0.142***
Log(FTE)	-0.030**	0.342***	0.152***	-0.034*	-0.008*
Constant	7.322***	9.214***	7.955***	9.805***	8.119***
Export Intensity	No	No	No	No	No
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.370	0.385	0.300	0.364	0.345
N	3,235	1,050	1,074	1,081	6,440

Notes: FTE = full time equivalent. Export data is not available for Finland
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.8 - Company size in Sweden

SECTOR	2-49	50-99	100-250	250+	TOTAL
Log (R&D capital/FTE)	0.110***	0.058***	0.029**	0.078***	0.107***
Log (Physical capital/FTE)	0.112***	0.147***	0.255***	0.236***	0.226***
Log(FTE)	-0.409***	-0.679***	-0.431***	-0.048***	-0.067***
Constant	11.800***	13.375***	11.796***	11.380***	9.410***
Export Intensity	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.599	0.718	0.478	0.443	0.429
N	1,055	566	892	1,535	4,048

Notes: FTE = full time equivalent.
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.9 – Green technology

SECTOR	DENMARK	NORWAY	FINLAND	SWEDEN	TOTAL
Log (R&D capital/FTE)	0.118***	0.122***	0.193***	0.11***	0.167***
Log (Physical capital/FTE)	0.13***	0.149***	0.098***	0.287***	0.142***
Log(FTE)	-0.001	-0.036	-0.013**	-0.086***	-0.008*
Constant	10.513***	10.06***	7.973***	8.576***	8.119***
Export Intensity	Yes	Yes	Yes	Yes	No
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.415	0.461	0.349	0.547	0.345
N	2,782	1,938	3,889	2,027	6,440

Notes: Export data is not available for Finland
***,** and * indicate significance at the 1, 5 and 10 percent level.

Table C.3.10 – Welfare technology

SECTOR	DK	NO	FIN	SE	TOTAL
Log (R&D capital/FTE)	0.144***	0.155***	0.241***	0.105***	0.107***
Log (Physical capital/FTE)	0.075***	0.098***	0.055***	0.177***	0.226***
Log(FTE)	0.048***	0.028***	-0.023**	-0.081***	-0.067***
Constant	10.234***	10.129***	7.936***	10.732***	9.410***
Export Intensity	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
R-sq.	0.366	0.375	0.383	0.463	0.429
N	2,087	1,050	2,101	997	4,048

Notes: FTE = full time equivalent. Export data is not available for Finland
***,** and * indicate significance at the 1, 5 and 10 percent level.

C.4 TEST FOR DIFFERENT COEFFICIENTS

In order to determine whether the estimated R&D and Capital elasticities (coefficients) are significant different between country pairs a Z-test is calculated. The results from the Z-test are presented in Table C.2.

Table C.4.1 – Test for different coefficients between country pairs

COUNTRY PAIR	R&D CAPITAL	CAPITAL
DK-NO	4.505***	0.000
DK-FIN	10.493***	1.001
DK-SE	2.284**	8.881***
NO-FIN	4.284***	1.078
NO-SE	2.535**	9.483***
FIN-SE	7.974***	10.837***

Source: DAMVAD
Notes: ***,** and * indicate significance at the 1, 5 and 10 percent level.

In order to determine whether the estimated R&D and Capital elasticities are significant different within a country a F-test is calculated. The results from the F-test are presented in table C.3.

Table C.4.2 – Test for different coefficient within a country

COUNTRY	F-TEST	P-VALUE
DK	F(1, 5744) = 21.4***	0.000
NO	F(1, 4584) = 0.1	0.753
FIN	N/A	N/A
SE	F(1, 4048) = 191.2***	0.000

Source: DAMVAD
Notes: ***,** and * indicate significance at the 1, 5 and 10 percent level.

In order to determine whether the estimated rate of return of business R&D investments are significantly different between country pairs a Z-test is calculated. The results from the Z-test are presented in Table C.2.3.

Table C.2.3 – Test for different return of investment between country pairs

INDUSTRY	Z-TEST
DK-NO	3.528*
DK-FIN	4.053*
DK-SE	6.008*
NO-FIN	0.008
NO-SE	2.494*
FIN-SE	3.25*

Source: DAMVAD

Notes: * indicates significant difference.

In order to determine whether the estimated rate of return of business R&D investments in welfare and green technologies is significantly different compared to the return from the business sector in total in Denmark a Z-test is calculated. The results from the Z-test are presented in Table C.2.4.

Table C.2.4 – Test for different return of investment in Denmark

COUNTRY PAIR	Z-TEST
DK-Green	0.121
DK-Welfare	10.968*

Source: DAMVAD

Notes: * indicate significant difference.

Central Innovation Manual on Excellent Econometric Evaluation of the Impact of Public R&D Investments

"CIM 2.0"

Ministry of Higher Education
and Science
—
Danish Agency for Science,
Technology and Innovation

Central Innovation Manual on Excellent Econometric Evaluation of the Impact of Public R&D Investments

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1. Preface

Excellent methods for the measurement of the impact of research and innovation policies is key for evidence-based policy-making. The field of quantitative impact assessments is in an on-going development. In 2011 the Ministry of Higher Education and Science launched its first manual on excellent econometric evaluation[1]: "*Central Innovation Manual on Excellent Econometric Evaluation of the Impact of Interventions on R&D and Innovation in Business* (CIM)". Due to new research experience, new impact assessments, improved data collection and longer time series it is time to update this manual in a version 2.0. CIM 2.0 establishes a set of agreed minimum analytical and data quality requirements and key performance indicator standards for econometric impact studies of public research and innovation programmes and policies. Furthermore, it provides an overview of the most important key performance objectives and indicators as well as of econometric impact assessments of the Danish research and innovation system.

Structure of the manual

The report is in three parts. Part I is a manual on excellent econometric evaluation of the impact of interventions on R&D and innovation in businesses, part II sets up standards for key performance indicators and part III presents an overview of key performance indicators and econometric impact assessments of Danish research and innovation policy.

Part I: Manual on excellent econometric evaluation of the impact of interventions on R&D and innovation in businesses

Nine principles which are important standards and minimum requirements for excellent econometric impact assessments are formulated on experiences with impact assessments of Danish R&D and innovation programmes and the latest research in the field.

Part II: Standards for key performance indicators

Part II gives an overview of a comprehensive set of input, output and impact performance indicators to measure the effect of research and innovation programmes e.g. in the cases where the main purpose of the programme may be non-economic activities or limited access to quantitative micro data and long-time series. Although CIM 2.0 lists standards for impact assessments, the intention has been to do this in such a way that there is room for flexibility.

Part III: Overview of the most important key performance indicators, impact assessments and results in Denmark

Firstly, this part provides an overview of the most important econometric impact assessments on the Danish research and innovation programmes and on the R&D systems and their impacts. Secondly, part III also contains an overview of the most common key performance indicators used in the studies of the Danish research and innovation programmes.

WHY CIM?

Policy makers and programme owners are constantly looking for the best and most solid methods to identify and verify the impact of policies. The Central Innovation Manual (CIM) is a guide on excellent methods for the conduct of economic as well as non-economic econometric impact assessments.

1 http://ufm.dk/en/publications/2012/central-innovation-manual-on-excellent-econometric-impact-analyses-of-innovation-policy-cim

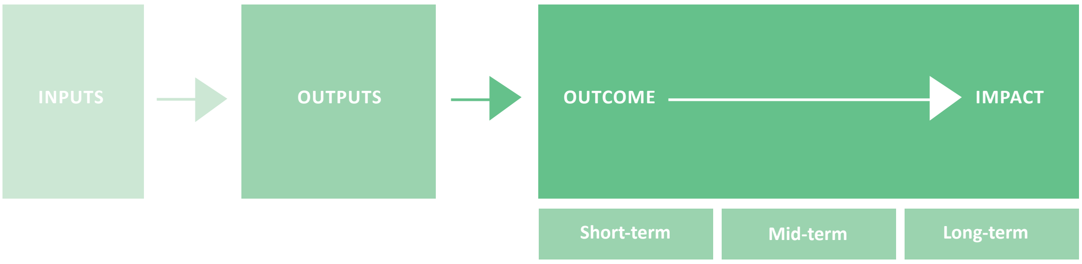
1.1
Acknowledgement

This manual has been developed in close cooperation with university researchers and private researchers. Furthermore, the manual has been discussed at workshops and seminars between 2010 and 2013 at Copenhagen Business School (CBS) and in the Ministry of Higher Education and Science and we have received valuable comments from several ministries, including the Ministry of Finance, the Danish Ministry of Business and Growth, the Danish Ministry of Climate and Energy, the Danish Ministry of Food, Agriculture and Fisheries, the Danish Ministry of Foreign Affairs and the Danish Ministry of the Environment. A special thank shall be given to Professor Anders Sørensen and Ph.D. Johan Kuhn at Copenhagen Business School (CBS) and to Michael Mark from DAMVAD Consulting A/S.

2 Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions: *"Measuring innovation output in Europe: towards a new indicator"*, final 624, 13 September 2013

2. PART I – What is CIM (2.0)?

Internationally, policy makers and programme owners have been working on monitoring and evaluating research and innovation programmes for the past couple of decades. The rigorous measurement of the impact of innovation policies is a key for evidence-based policy-making.[2] Due to many economic challenges and international competition between countries and who wants to be among the leading countries in terms of R&D and innovation, policy makers are demanding impact of and accountability from research, development and innovation programmes and policies. Impact assessments can provide robust and credible evidence on performance and on whether a particular program achieved its desired outcomes and impacts.



Impact assessments are part of a broader agenda of evidence-based policy making. This growing global trend is marked by a shift in focus from inputs and outputs to outcomes and impacts. The increased focus has been encouraged, among others, by OECD,[3] who has focused great attention on the area through a coordinated effort among most of the 27 EU countries, Korea, Norway, Switzer-land, Russia, Turkey, South Africa and most of the countries in South America.

WHAT IS CIM 2.0?
Central Innovation Manual on Excellent Econometric Evaluation of the Impact of Interventions on R&D and innovation in Business (CIM 2.0) focuses on econometric outcomes and impact assessment methods when analysing investments in public and private research, development, education and innovation.

The vision of the Danish Agency for Science, Technology and Innovation[4] is that the econometric impact assessments of Danish public research and innovation programmes and policies will be among best practice in international contexts over the coming decade.[5] The objective of CIM 2.0 is to establish minimum requirements and standards on methods and data that are necessary for the implementation of excellent econometric impact assessments of the innovation and research policy.

3 OECD (2008), Science, Technology and Industry Outlook

CIM 2.0 is the result of the evaluation strategy of the Danish Agency for Science, Technology and Innovation, which started as a 5-year research and innovation project about performance measurements in the innovation field. The main elements of the 5-year project are the more than 20 evaluations (see chapter 4.1) which have been conducted from 2007 to 2011. The research project has been extended to 2014 and includes now more than 30 econometric impact studies and evaluations.

CIM 2.0 has been implemented in accordance with the most recent and best econometric research methods, which facilitates publication of methods and results in the most respected international journals in the relevant fields.

TEXT BOX 1. DEFINITION OF IMPACT ASSESSMENT

Impact assessments are a particular type of evaluation that seeks to answer cause-and-effect questions. Unlike general evaluations, which can answer many types of questions, impact assessments are structured around one particular type of questions: *What is the impact (or causal effect) of a program or a policy on an outcome of interest?* This basic question incorporates an important causal dimension: We are interested only in the isolated impact of the program or policy, that is, the effect on outcomes that the program or policy directly causes. The basic form of impact assessment will test the effectiveness of a given policy or program. Qualitative data, monitoring data and evaluations are needed to track program and policy implementation and to examine questions of process that are critical to informing and interpreting the results from impact assessments. In this sense, impact assessments and other forms of evaluation are complements for one another rather than substitutes.

The primary target groups of CIM 2.0 are programme owners and policy makers in the Danish ministries, government agencies and regions working with programmes and policies on research and innovation. Other target groups are external expert stakeholders, evaluation experts (from organisations, regions, research, technology, education and knowledge institutions etc.) , researchers, trade unions and business associations who are interested in following and having a dialogue with the Ministry of Higher Education and Science on how to conduct impact evaluation studies and how to docu er words anyone interested in econometric impact evaluation in ministries and agencies.

CIM 2.0 is not identical to the work done in other countries[6] since the key objective is to establish a clear set of minimum requirements for how to conduct so-called excellent econometric impact assessments of innovation policy. CIM 2.0 establishes a framework for a “standard” impact assessment procedure which makes it possible to conduct excellent impact assessments of interventions on research and innovation programmes in business that makes it possible to compare the impact of different programmes. Hence, CIM 2.0 is not an attempt to establish practical guidance on a broader number of methods on how to evaluate the wider impact of research and innovation programmes on business. In this way CIM 2.0 complements existing documents and reports.[7]

Although CIM 2.0 lists requirements and standards for impact assessments, the intention has been to do this in such a way that there is room for flexibility and diversity. The purpose of the manual is also to contribute to the international discussion and the knowledge about excellent methods for performance measurements in research, innovation and business policy.

Since excellent impact assessments requires good researchers and evaluators, financing of research and evaluation projects, and unlimited access for researchers to relevant qual-

4 In the Ministry of Higher Education and Science: http://fivu.dk/en?set_language=en&cl=en

5 In the reports ‘Clusters Are Individuals – Benchmarking Insights from Cluster Management Organizations and Cluster Programs’ by Kompetenznetze Deutschland (VDI/VDE Innovation + Teknik), 2011, and ‘Service innovation: Impact analysis and assessment indicators’ by the European Commission’s Pro-Inno Net EPISIS, 2011, the Danish Ministry of Science’s econometric performance measurements are singled out as being among international best practice.

6 See *Guidance on evaluating the impact of interventions on business*, Department for Business, Innovation and Skills (BIS), august 2011

7 E.g. The role of evaluation in evidence-based decision-making, Department for Business, Innovation and Skills (BIS), august 2010, and The Green Book – Appraisal and Evaluation in Central Government, Treasury Guidance, London, United Kingdom, and The Magenta Book: guidance notes for policy evaluation and analysis, Government Social Research Unit, HM Treasury, London, United Kingdom (October 2007) ity data on public programmes and policies, close interaction between researchers and evaluators on the one side and the contractors, programme owners and policy makers on the other side must be established. Excellent econometric impact assessments of public programmes and policies must be built on mutual respect and trust.

The success factors of an excellent impact assessment might also depend on to what extent the evaluation is focused on a relevant and limited set of impact variables and tailored in terms of methods. Furthermore, the relevance and outcome of an evaluation will also depend on the consistency between the evaluation approaches and the requirements of the programme sponsor. In this context a close relationship and high level of interaction between the programme sponsor and the evaluators could lead to the formulation and implementation of an effective and useful evaluation (useful in the sense that the study contributed to policy learning).

This view is also reflected in a large European study on the evaluation practices and methods in the European countries. For instance this point was made by Technolopolis in an evaluation of the econometric impact study of the Danish Innovation Consortium Scheme (see the text box below). The study of the Danish Innovation Consortium Scheme can be seen as an example of the type of excellent econometric impact assessments of R&D and innovation policies which is the subject matter of this manual.

EVALUATION BRIEF BY TECHNOLO-POLIS ON: "AN ANALYSIS OF FIRM GROWTH EFFECTS OF THE DANISH INNOVATION CONSORTIUM SCHEME"
Interviewer and case study author: Paul Cunningham, Manchester Institute of Innovation Research

1. Introductory information
The Danish Innovation Consortium Scheme is a national subsidy scheme operated by the Danish Council for Technology and Innovation (RTI) in cooperation with the Danish Agency for Science, Technology and Innovation (DASTI). The econometric impact evaluation of this scheme was titled: "An Analysis of Firm Growth Effects of the Danish Innovation Consortium Scheme" and it was an interim evaluation, commissioned by the Danish Agency for Science, Technology and Innovation. The evaluation was carried out between September 2009 and April 2010 by J.M. Kuhn from the Centre for Economic and Business Research, Copenhagen Business School. The evaluation budget was approximately €40,200. The evaluation examined the economic impact. In a counter-factual analysis, the evaluation examined 220 firms which had participated in at least one Innovation Consortium using a firm-register dataset. The focus is on firm level developments in two success parameters: gross profit and employment. Innovation Consortia subsidise and facilitate cooperation between private firms and research and knowledge institutions, thus contributing to the dissemination of knowledge and research results from the research sector into the business sector.

2. Summary
The objectives of the evaluated measure were as follows: through the creation of innovation consortia (consisting of a minimum of two companies, a research institution and a knowledge dissemination party), to promote joint projects that develop and bring research-based knowledge to maturity to the benefit of Danish companies and the Danish business community – especially SMEs. The objectives and main questions of the evaluation were: to determine the economic

impact of the measure (in terms of employment growth and gross profit) and on survival rates on participating firms compared to a control group of non-participants.

The evaluation methodology was the culmination of a specific research project approach sponsored by the commissioning agency and the evaluator. The approach and main research methods involved a control group comparison on specific growth factors (namely, gross profit and employment). The key information sources included information derived from programme monitoring data (on participants), earlier evaluations (in 2007 and 2008), company financial reports (from an external public domain dataset) and mergers and acquisitions data (again in the public domain).

The key findings of the study were that firms that participated in the Innovation Consortium scheme experienced significant increases in the growth of gross profit and employment when controlling for pre-participation growth and developments in the growth of firms in the control group. However, the effects were less marked for larger participating firms than in the case of smaller companies (gross profit <$20m or <150 employees). No differences in survival rates were detected. In terms of the lessons for evaluating innovation support measures, the (relatively simple and limited) analysis approach was found to be favourable for this type of programme, although regular updates to the data might add additional sophistication – e.g. by identifying those firms that benefit most or which Innovation Consortia work better than others. It should be noted that other attributes of the measure (management and process issues, participant interactions) were also evaluated through separate targeted evaluations.

3. Conclusions and lessons learned

The evaluation was successful in that it developed a methodology highly consistent with the objectives set by the commissioning body (the Danish Agency for Science, Technology and Innovation) which addressed a rather narrow set of questions, i.e. to assess the economic impact of the IC Scheme on participating companies. This level of consistency was achieved by the close relationship and level of interaction demonstrated between the evaluators and the contractors and through the opportunity to apply the methodology in two separate evaluations, allowing further refinement of the approaches used. The personal engagement and high level of interest of the key sponsor (the Head of the Centre for Strategic Research and Growth within the Danish Agency for Science, Technology and Innovation) could also be highlighted as a major contributory factor to the success of the methodology. Overall, the entire process was described as “very smooth” by the evaluator. With regard to the approach itself, the programme manager noted that the evaluation had delivered a high degree of utility: it had provided essential answers to specific questions that were required for political justification and budgetary requirements and it had provided a clear quantitative evidence of the programme’s success. Moreover, it had led to the development of a methodology that was both replicable and transferable. As noted it was highly dependent on the availability of good quality comprehensive data on both the participating firms and on the control group of firms required for the counterfactual analysis. This also makes the requirement for such high quality information a potential limiting factor to the adoption of the approach in other contexts. In the absence of existing data sources, it would be necessary to expend more evaluation resources in order to develop the necessary data. Moreover, it would not be routinely updated as is the case in Denmark. However, it should be noted that the evaluator let it be known that the use of the method was also being explored as a potential methodology for evaluating Eureka programme participation. It was also noted that the same approach was being applied in other Danish innovation support schemes such as the Industrial PhDs Scheme, International Collaboration Projects and the Innovation Assistance Scheme.

A careful selection process was utilised in defining the group of control firms, which ensured that these were very similar to the participating firms in terms of their characteristics prior to their involvement in the Scheme. This reduced (but did not entirely remove) the possibility that extraneous factors might be responsible for any observed deviations in the economic growth variables between the two groups as a consequence of participation in the Scheme. Since the evaluation methodology was relatively straightforward, its use by other evaluators would not be particularly limited by a need for advanced or specialist competencies. By admission, the evaluation did not address a number of issues that are typically significant for this type of innovation support measure, such as participant satisfaction, uptake statistics and the rationales for participation, management and administrative process issues, knowledge transfer aspects, impacts on other IC participant partners, outputs (e.g. publications, patents) and their associated quality issues, etc. The contractor estimated that it only delivered about 20% of the total amount of information required for the full evaluation of the IC Scheme; however, this was fully recognised. Thus, separate accompanying evaluations have also been conducted, using different evaluators and over different timeframes into these specific aspects.

This approach carries lessons for the evaluation of programmes more generally in that it offers the opportunity to conduct separate, more targeted evaluation studies, performed by different evaluators with distinct capabilities and expertise rather than undertaking a single one-off more comprehensive evaluation. This is particularly useful in cases where timing issues may be important as it avoids having to make a trade-off between carrying out an early-stage evaluation to obtain the management/process information which might indicate the need to change the way in which the scheme is administered, or a mid-term evaluation in which emerging networking and knowledge transfer/output effects might be assessed or finally a longer term evaluation in which various aspects of impacts might be assessed.

To summarise, the main conclusions are:

- The evaluation was highly focused on a limited set of impact variables and thus was fully tailored (in terms of methods and timing) to assess the programme effects in this context.
- The evaluation's success was in part attributable to the consistency between the evaluation approaches and the requirements of the programme sponsor.
- The close relationship and high level of interaction between the programme sponsor and the evaluators led to the formulation and implementation of an effective and useful evaluation (useful in the sense that the study contributed to policy learning).
- The success of the principle study methodology was predicated on the existence and availability of comprehensive and robust firm-level data.
- The study was able to utilise this data to produce reliable comparison data sets of participants and non-participants.
- Given the preconditions outlined above, the methodology appeared to offer good scope for its application to the evaluation of other similar schemes.
- The broader evaluation approach using variable timings and appropriate methodologies offers lessons for future evaluations.

Further information: http://ufm.dk/publikationer/2010/effektmaling-af-innovationskonsortier-2013-an-analysis-of-firm-growth-effects-of-the-danish-innovation-consortium-scheme

3. Overview of important standards and minimum requirements – The 9 principles

The central challenge in carrying out effective impact assessments is to identify the causal relationship between the project, programme and the outcomes of interest. Hence, CIM 2.0 requirements on excellent econometric impact assessments are (1) a high quality of data, (2) the most recent research-based statistical methods and (3) a high quality of control groups. On this basis, guidelines are set out in CIM 2.0 in the form of nine principles phrased as minimum requirements on excellent impact assessments.

9 principles: Minimum requirements on excellent econometric impact assessments

DATA	**1. Data quality and harmonisation of data collection** Establish standards for data collection, including standards for input data and registration in databases for each research and innovation programme. • Standards for data collection are harmonised across all research and innovation programmes in the Danish Agency for Science, Technology and Innovation's database (The Innovation Denmark Database). • Input data should be of the highest quality so it can be linked to national and international statistics and databases.
DESIGN	**2. Selection of comparable companies and/or individuals as control groups** Selection of comparable companies and/or individuals for control groups must be based on matching as many relevant observed characteristics as possible. The very highest requirements on quality and interpretation of data for control groups must be stipulated. Selection of control groups: • Use of the propensity score and nearest neighbour matching method for 9 selection of the most comparable control group • Alternative methods like lottery and ranking could also be considered, e.g. in robustness tests (see principle 6)
	3. Difference-in-difference method Use of the difference-in-difference method and balanced panel data.
	4. Treatment of outliers Outliers must be handled in accordance with the most established international methods in the fields of economic research and econometric methods.
	5. Long-time series Ensure high data quality with long time series of at least 6-15 years with a minimum of data gaps in the time series. National statistics on company data and personal data as well as DASTIS' Innovation Denmark Database for research and innovation programmes are to be established with time series of up to 20-25 years depending on the instrument applied.
	6. Robustness test Robustness tests are recommended in studies with long time series and many observations. In case of data limitations, e.g. limited time series and observations, it is a requirement that impact assessments be carried out using methods that thoroughly test the robustness of the results.
INTER-PRETATION OF RESULTS	**7. Relative impact indicators** The key performance indicators are to be made relative in order to avoid comparison of uneven entities, e.g. through differences in growth rates or other relevant types of ratios.
	8. Peer review of results The quality and utility value of impact assessments must be discussed with independent research organisations that are not behind the analyses, e.g. through peer reviews, research seminars, policy maker workshops etc. Preferably, the results of the impact evaluations should be suitable for acceptance by the most reputable international journals.
CRITICAL ISSUES	**9. Failures and stress tests** Impact studies also contribute to policy learning. Policy makers and programme owners should accept critical issues, failures of results, collapse of projects and programmes etc. as a part of an evaluation. The contractor of the evaluation should try to learn of failures and not only look for success stories. A close relationship and high level of interaction and mutual trust between the programme sponsor and the evaluator increase the possibility of the formulation and implementation of an effective and useful evaluation, useful in the sense that the study contributed to policy learning and new knowledge about the weaknesses and strengths of the programme.

3.1
Principle 1 – Data quality and harmonisation of data collection

Good quality data are required to assess the impact of a research or innovation. At a minimum input data are needed to know when a programme or a policy starts and who participates in the activities. Input data are data collected by programme owners, often at the point of service delivery, as part of regular operations. Both projects that approved and rejected projects should be registered systematically. Data from rejected projects can be useful in selecting a control group. As a standard the following input data are collected for all research and innovation programmes:

- Variables for each project: Name of programme, project title, grant status (rejection or approval), application year, start date for the project, end date for the project, total budget and total grant
- Variables for the participating partners in each project: Company registration number (CVR-number), name, postal code, region, number of employees, industry (NACE code).
- Variables for the participating individuals in each project: Civil registration number (CPR), name, sex, age and education.

The input data for every research and innovation programme in the Danish Agency for Science, Technology and Innovation is harmonized and are part of the InnovationDenmark database.

Furthermore, collection of input data is included in the design of every new research and innovation programme and not when a programme needs to be evaluated.

It is important to determine the data needed and the sample required to precisely estimate differences in impacts between the participants in a programme and the control group. Input data are not sufficient for impact assessments, and therefore national or/and international statistics are used. The following national statistics are used in connection with the impact assessments:

- R&D statistics (Statistics Denmark)
- Accounts statistics (Statistics Denmark)
- Community Innovation Survey (CIS) (Statistics Denmark)
- Education statistics (Statistics Denmark)
- Patent statistics (Statistics Denmark)
- Labour market statistics (Statistics Denmark)
- Salary statistics (Statistics Denmark)
- The Danish Commerce and Companies Agency's Central Business Register / Købmandsstandens Oplysningsbureau/Experian A/S (Danish Business World's Information Agency)
- The research indicator (The Danish Agency for Science, Technology and Innovation)

The company registration number or civil registration number is some of the most important input data to collect for each participant because that is the linkage between the input data collected for each programme and national statistics.

It is important as a minimum that sorting of observation and cleaning of data is done in the same way for research and innovation programmes that are to be compared[8].

3.2
Principle 2 – Selection of comparable companies and/or individuals to control groups

The impact of participating in a research and innovation programme is often indirect and therefore difficult to measure and identify. It is difficult to isolate the actual impact that may be the result of many and varying external factors. It is also difficult to identify the causality of participating in a research and innovation programme.

The selection of control groups is important in relation to the issue of causality. When selecting company or individuals control groups, companies or individuals must be chosen that are more or less equally likely to participate in the programme, yet they do not.

8 Examples of a comparison of progammes is the comparison of ordinary PhDs and industrial PhDs found in DASTI/FI(01/2011), and the comparison of companies participation in EUREKA projects and innovation consortia found in DASTI/FI(15/2011).

When selecting control groups, it is also important to consider that the companies or individuals that participate in a programme are to be compared with other companies or individuals that are not participating, but are similar in as many relevant parameters as possible that may be of significance to the impact of the analysed programme.

Matching methods typically rely on observed characteristics to construct a control group. Finding a good match for each programme, a participant requires approximating as closely as possible the variables or determinants that explain that individual's decision to enrol in the programme.

Even through companies are comparable in observed characteristics, they can be very different in unobserved characteristics such as strategy etc. Hence, the group of companies or individuals participating in a given programme is not necessary comparable with the group of companies or individuals that did not participate. A difference in outcomes between the two groups may be attributable to differences in firms' characteristics as to the programme. The correlation between participation and outcome in the case of selective use is therefore an unreliable estimate of the programme's causal effect.

WHY IS THE CONTROL GROUP IMPORTANT?
The results of an impact assessment cannot be better than the choice of the control group of the evaluation.

Therefore, a standard is recommended for the establishment of control groups based on a minimum observed characteristics. In this way, a basis is established for making it probable whether there is a causal connection between the factor to be analysed and the performance objective, along with the basis for measuring the isolated impact, but this also depends on the programme that is to be analysed.

MINIMUM REQUIREMENTS FOR SELECTING A CONTROL GROUP OF COMPANIES	MINIMUM REQUIREMENTS FOR SELECTING A CONTROL GROUP OF INDIVIDUALS
• Educational level of the company's employees R&D intensity • R&D department • Export intensity • R&D investments • Profit, surplus or contribution margin • Company size • Industry affiliation	• Education • Institution • Company size • Industry affiliation • Gender and age • Any other socioeconomic variables, such as salary, background etc.

It should be assessed whether a control group should be established solely based on R&D-active companies, or whether innovative companies and non-innovative companies should also be included. If the control group consists solely of R&D-active companies, this must be justified, e.g. by the fact that the analysed activity or the analysed programme is not an activity that all companies can launch overnight, but that it is restricted to R&D-active companies only.

This is a strict assumption, which will undoubtedly exclude companies that were predisposed for the analysed activity. Conversely, it may also be a conservative assumption that helps ensure robustness in the results, as it avoids comparison with companies where the probability of participation in the activity in question is very small. By collecting input data for every regional and national research and innovation programmes it is also possible to make a control group of companies or individuals that has not participated in similar programmes as the programme under evaluation.

The minimum requirements are that as many different characteristics as possible are taken into account. However, it is important to avoid including too many explanatory variables, which may give overlapping results, either individually or in combination. By including too many identical variables, there is a risk that multicollinearity will occur along with too great a correlation between the explanatory variables. This means that the parameters become insignificant and the result becomes biased. An example is if R&D intensity is included along with R&D investments, R&D department and company size, as there is interdependency between these variables.

There are different ways to select a control group of companies or individuals which more or less have the same possibility in participating in a research and innovation programme as the once that do.

Above we have described a randomly chosen control group of companies or individuals on observed characteristics. But the observed characteristics can be combined with other factors.

The control group of companies or individuals can be chosen from the companies or individuals that applied, but did not receive funding. There can still be differences between the top companies or individuals in the funded sample and the worst companies or individuals among the unfunded ones so the control group still suffers from selection bias and unobserved heterogeneity.

In the case where the applications get a score the control group could be companies or individuals with projects situated just above and below the funding cut-off, where it is similar ex ante companies or individuals except in their probability of funding.

Another way to find control groups that do not participate, but could have done so, is to have a lottery between the applicants. That is the simplest way to isolate the effect of the programme because it is totally randomly who is funded and who is not. That is possible for research and innovation programmes where there is an evaluation with a minimum score but no ranking, or no evaluation or score of the applications other than they have to fulfil the administration criteria.

3.2.1 *Control groups may be selected using a so-called 'propensity score matching' and 'nearest neighbour' method.*

Based on a large number of impact studies and research articles which have been conducted by Danish researchers, R&D consultants and the Danish Council of Technology and Innovation the recommended standard method is the "Propensity Score Nearest Neighbour Matching Method", which is used to establish and delimit, on a one-to-one scale, the group of R&D-active companies (or innovative enterprises) that participate in an instrument, and a statistically comparable control group of R&D-active companies (or innovative enterprises) that do not participate, but could have done so. It is impossible to find a control group that is completely identical.[9]

The probability models for companies' participation in an instrument, which are used for identification of the factors that have an impact on whether the R&D-active companies are included in the instrument in question, are set out as logistic regressions and used in connection with the Propensity Score Matching method.

In most cases, it will be an advantage to put together a control group that has as many control companies as possible – based on the law of large numbers. Therefore, one-to-one is a minimum requirement, but the standard should be one-to-many. Furthermore, this should be supplemented by balance tests in order to analyse the difference between the treatment group and the control group.

The so-called propensity score matching method is used to match companies or individuals who have participated in the analysed activity with comparable R&D-active or innovative companies or individuals who have not participated in an equivalent activity. The idea of the method is that for a company T, which has the desired activity, a company C is found among the other companies in the relevant statistics, which in a number of statistical param-

9 Examples of application of this method are found in DASTI (Innovation: Analyse og evaluering 01/2010): "*Productivity impact of business investments in research, development and innovation",* DASTI (Innovation: Analyse og Evaluering 02/2011): *"The economic impact of business-research collaboration*", and DASTI (Innovation: Analyse og Evaluering 03/2013), *"Economic impacts of Business Investments in R&D in the Nordic Countries – A micro-economic analysis".*

eters resembles company T by having the same probability ('propensity score') of taking part in the relevant activity, except that in actual fact, company C has not participated in the activity. In this way, company T (which is designated 'treatment' or 'participating' company) can be compared to a similar company C (which is designated 'comparison company' or 'control company'), which has been found in the statistics. Statistically, company C must resemble company T in regards to industry, company size, export pattern, staff education, profit, contribution margin and composition as well as R&D activities or innovation activities.

Other methods like establishing control groups based on information from the ranking of projects in the evaluation process can also be used. The advantage of this method is that the control group consists of observations with enterprises and researchers which applied for participation in the programme or initiative but where the application was rejected based on the evaluation criteria. However, obviously not all applicants should be part of the control group. Controls should be based on those applications which had almost the same ranking score in the evaluation process but were rejected due to financial limitations of the support programme. Observations based on the treatment group and the controls should only be from those projects which are just above and just below the threshold leaving the best and the worst projects out of the sample.

However, such an approach requires an excellent and trustworthy ranking system based on a large number of projects which have been evaluated and a large number of observations close the threshold. This type of quality data based on ranking information may exist in the EuroStars-programme of the European Union, the framework programmes of the European Union and in the Innovation Consortia Programme of the Danish Ministry of Higher Education and Science. However, there is no scientific evidence that a control group based on high quality ranking observations produces a better control group than the "Propensity Score Nearest Neighbour Matching Method".

WHAT IS THE RECOMMENDED METHOD TO ESTABLISH A CONTROL GROUP?
The recommended standard method is the 'Propensity Score Nearest Neighbour Matching Method'. Other methods like using ranking information can also be used but there is no scientific evidence that a control group based on ranking information produces a better control group than the "Propensity Score Nearest Neighbour Matching Method".

It naturally follows that it is not possible by using this or other methods to find a control group that is completely identical in all partially unobservable factors. Another selected control group may give different results. It is therefore important to be able to interpret the characteristics found in the control group.

3.3 Principle 3 – Use of the difference-in-difference method and balanced panel data

The possibilities depend on the design of the innovation policy instruments. For instance, some innovation policy instruments may be able to open up for considerably more precise estimates of the effects than the matching described above and the difference-in-difference method described below. This depends on whether, for instance, a regression-discontinuity design is a possibility.

3.3.1 The difference-in-difference method

One of the recommended central statistical methods that have been used is the difference-in-difference method. This method is used to calculate differences in the development at the treatment group and the control group of statistically identical companies or individuals without the analysed activity.10

10 Examples of application of this method are found in DASTI (Innovation: Analyse og evaluering 01/2010): *"Productivity impact of business investments in research, development and innovation"*, and DASTI (Innovation: Analyse og Evaluering 02/2011): *"The economic impact of business-research collaboration"*.

The difference-in-difference method is based on comparison of changes in output (the performance objective). The model therefore looks as follows:

$$\delta = Y_1^T - Y_0^T - \left(Y_1^C - Y_0^C\right)$$

In which δ is the effect of the activity, which is calculated on the basis of the difference between the development in the performance indicator, called Y, at the treatment group (T), defined as the performance indicator at time 1 minus the performance indicator at time 0, and the development in the performance indicator at the control group (C), defined as the performance indicator in time 1 minus the performance indicator in time 0. Whether there is a significant difference between the two can be tested subsequently by means of e.g. standard t-tests or linear regression.

Box 1

Overview over impact assessments of programmes and policies

Difference-in-difference:

(a) before-after comparison of companies that participate in the scheme (participant)

(b) before-after comparison for companies that do not participate in the scheme (control)

See whether (a) is more positive than (b).

T1 – success parameter of participant before.

T2 – success parameter of participant after.

C1 – success parameter of non-participant before.

C2 – success parameter of non-participant after.

The difference (T2-T1)-(C2-C1) measures the difference in the increases.

3.3.2 Balanced panel data

The effect of companies' research and development investments on added value and productivity per employee is a dynamic process, which may vary over time. Cross-sectional analyses based on a single year are not adequate for analysis of the variation over time. Furthermore, there may be unobservable effects on the individual company, which the models are not able to take into consideration. The before and after comparison that results from applying the difference-in-difference method means that panel data (cross-sectional data over time) and methods are needed to check these unobservable effects.

Large companies are included in the research and development statistics every year, while samples from among small and medium-

WHAT IS THE KEY METHOD FOR IMPACT ANALYSIS?

The key method for analysis of the difference between the participants in the policy initiative and the control group which does not participate is the difference-in-difference method.

sized enterprises are selected randomly. The result is a very 'unbalanced' panel. For some companies, observations are available for all years, while others only have data for one or a few years. Because of this, it is recommended that the panel data set should be put together as follows:

- Panel data analyses are only to be made for companies with at least two observations. In order to ensure that the analyses are as representative as possible, all companies with two or more observations are to be included. If the data basis allows for this, the requirements may be made more stringent, so that only companies with three or more observations are included. Naturally, this will reduce the number of companies in the analysis.
- The following approach is recommended for missing observations in time series: If a single observation is missing in a time series, the single missing observation should be estimated. If two or more years are missing in the time series, the most recent continuous part of the time series should be kept.
- Extensive changes in the variables may indicate a merger or division of the company. Such changes may have a disproportionately large effect on the results. It is recommended that the standard in part of the international literature be followed, and that companies with annual growth rates in added value, fixed assets, number of employees or R&D capital of less than - 50 % or more than 300 % be removed. This is in accordance with the standard set out in international literature.
- It is recommended that sensitivity analyses be carried out when basic data are changed.

3.3.3 Standards for calculating economic effects

The Cobb Douglas productivity function is used as a standard for indicating the effects of a given instrument in pounds and pence in the form of increased productivity per employee, profit etc. This is typically modelled as an OLS regression.[11]

11 Examples of the application of this method may be found in DASTI (Innovation: Analyse og Evaluering 02/2011): "The economic impact of business-research collaboration", and DASTI (Innovation: Analyse og Evaluering 03/2013), "Economic impacts of Business Investments in R&D in the Nordic Countries – A micro-economic analysis".

Depending on the chosen key performance indicator (the analysed success variable), changes of levels over time may also be relevant. An example of changes in levels would be changes in the number of employees and in the level of employment.

An example of relative changes would be the survival rate of companies or the employment quotas. Examples of changes in growth rates are the growth in productivity per employee, the growth in turnover or the growth in added value in the companies. In general, the standard for calculating the economic effects depends on the key performance objectives that are assessed and estimated.

When selecting background factors, it is important to consider how the individual background factors influence both outcome and treatment. For instance, there may be a time-related challenge with background variables, which might be affected by treatment in a model that includes lagged variables.

3.4
Principle 4 – Treatment of outliers

Outliers are observations which do not follow the pattern of the other observations. In order for results to be as representative as possible, econometric models should be able to measure effects in a wide range of companies. However, extreme values may distort the effects and reduce precision. In some cases, there may be good reasons for removing extreme values. An example is young companies where large and risky investments are made, which affect the companies' added value for a short period of time. Such companies will potentially experience extreme increases from one year to another.

However, whether or not extreme values should be removed depends on the purpose of the analysis and the innovation policy instrument. Therefore, a careful assessment of outliers should be made for each analysis and each instrument before any decision to exclude these from the analysis is made.

Furthermore, data have been found to include extreme values measured against e.g. companies' average productivity per employee, added value, employment etc. These are assumed to be incorrect registrations, which are connected either to the company's added value or to the number of full-year equivalents. Regardless of where the incorrect registration is found, it is recommended that such values be removed from the data. However, there may be other methods, e.g. to include or exclude extreme data to see whether this has any effect on the results, or to consider medians etc.

3.5 Principle 5 – Long-time series

Impact assessment is complex as a linear connection between the analysed activity and a subsequent effect is hardly ever found. Therefore, there are a number of conditions that may make it difficult to measure the impact, such as potential time layers before the impact sets in, different starting points for the companies, differences between the companies' characteristics and the companies' experience and competences in relation to the instrument.

As a standard, the econometric models must therefore be able to make allowance for time lag between the analysed activity and the impact thereof. The impact may set in with varying delays.

3.6 Principle 6 – Robustness test

The researchers checked the robustness of results to various matching procedures. They stress that their estimates might be biased because of some unobserved characteristics. Indeed, when using matching methods we can never rule out bias caused by unobserved variables, and that is their most serious limitation.

3.7 Principle 7 – Impact indicators should be made relative

It is not always easy to identify and delimit effects. Furthermore, differences occur in valuation depending on players and stakeholders. In this connection, an example is related to a company's market value. One suggestion is to use the market's valuation of the individual company as a measure for the price or value of the total 'tangible' and 'intangible' assets. However, this would require the companies in the analysis to be quoted on the stock exchange. Therefore, this method is not used, as most companies are not quoted on the stock exchange.

When effects in companies are to be analysed, it is recommended that a key performance indicator be used, which is made relative in relation to labour input. By making the indicator relative in relation to labour input, it is ensured that the effects cannot be attributed to an endless supply of labour.

3.8 Principle 8 – Peer review of results

The quality of impact assessments must be discussed with independent research organisations that are not behind the analyses, e.g. through establishing steering groups or conduction peer reviews, research seminars, policy maker workshops etc. The intention is to carry out impact assessments based on the best and most accepted international research-related and statistical methods. Preferably, the results of the impact assessments should be suitable for acceptance by the most reputable international journals or at high-level international conferences.

3.9 Principle 9 – Failures and stress tests

Impact studies also contribute to policy learning. Policy makers and programme owners should accept critical issues, "stress tests" of the programme, failures of results, collapse of projects and programmes etc. as a part of an evaluation. The contractor of the evaluation should try to learn for failures and not only look for success stories. A close relationship and high level of interaction and mutual trust between the programme sponsor and the evaluator increase the possibility of the formulation and implementation of an effective and useful evaluation, useful in the sense that the study contributed to policy learning and new knowledge about the weaknesses and strengths of the programme. The impact analyses should not only be restricted to areas and impact indicators where there is a high likelihood for success of the programme but the contractor of the evaluation and programme owners should also look for failures and areas where the programme does not create desired impacts and activities.

4. PART II - Standard for performance objectives: Key performance indicators

Although CIM 2.0 lists principles and minimum standards for impact assessments, the intention has been to do this in such a way that there is room for flexibility. This is partly because the recommended “Propensity Score Nearest Neighbour Matching Method” will not be the most relevant method for all types of research and innovation programmes and policy initiatives. This will be the case, for instance, when the direct business-related performance objectives are not the object of analysis, but where the study has a wider focus. In the case of other programmes and initiatives, it will be less relevant to make impact evaluations of the listed economic performance targets, because the main purposes of a programme and initiative may be other non-economic activities.

This is the case e.g. when impact evaluations are carried out in relation to clusters and innovation networks, research platforms and networks etc. where the main objectives are not necessarily economic performance targets alone, but may also include non-economic behaviour-regulating performance objectives. It is therefore important that concrete impact evaluations take into consideration what the objective of a given programme or initiative is.

At the same time most of the countries do not have the same possibilities as Denmark and for instance Norway, Sweden and the Netherlands, due to limited access to national wide quantitative micro data and very long time series. In the majority of the countries, it is difficult to establish the micro data for the whole economy basis needed for carrying out solid and validated quantitative econometric analyses that can document and calculate the effects of businesses’ research and innovation policy historically.

Therefore, the manual also includes an overview of the non-economic performance indicators for the most important research and innovation programmes and policy initiatives of the Ministry of Higher Education and Science.

The Ministry of Higher Education and Science has headed an international working group on performance indicators in the EU Pro-INNO project called EPISIS. This working group had participants representing government agencies, ministries and researchers from 8 countries including Denmark, Sweden, Norway, Slovenia, Austria, Germany, United Kingdom and Finland as well as the European Commission. Good practice on evaluations and performance indicators was exchanged, and a manual was elaborated with recommendations for indicators that can be used for setting out performance objectives and key performance indicators.[12]

The EPISIS report from 2011 on Impact Analysis and Assessment Indicators was

12 EPISIS Report (2011), *Service innovation: Impact Analysis and Assessment Indicators.*

also an integrated part of the work of a group of policy makers, programme owners and researchers from Denmark, Estonia, Finland, Germany, Iceland, Lithuania, Norway, Poland, Sweden, United Kingdom and the United States of America which met in Copenhagen and Berlin in 2011 and 2012 in order to develop a common understanding on cluster and network policies and world-class benchmarking, monitoring, evaluation and impact assessment tools and indicators. As a result of this work a number of recommendations on possible key performance indicators, impact assessment methods and benchmarking and monitoring tools were recommended in the publication "Let's make a perfect cluster policy and cluster programme – smart recommendation for policy makers." Based on international best practice a perfect evaluation league consisting of benchmarking, monitoring and impact analyses in the following three levels was recommended in the publication.[13]

4.1 Ex ante evaluation

An account of objectives and expected effects of the programme should be given for each research and innovation programme in separate performance descriptions. Thus, the performance description should include, among other things, an ex-ante evaluation of the programme.

On this basis, the Danish Agency for Science, Technology and Innovation sets out key performance indicators for each research and innovation programmes. These indicators can be key performance indicators in the form of so-called input, output, outcome and impact indicators. It is important to set out the key performance indicators in the design of every new research and innovation programme and not when a programme needs to be evaluated.

The assessments and recommendations for the selection of indicators follow the work from the EPISIS project[14] and the work in connection to the recommendations for cluster programmes and policies[15], which focus on innovation in services and creation of effective R&D and innovation cluster programmes, respectively, but can be inspiration to other programmes, as well as national legislation.

4.1.1 Input and output indicators

The aim of the input indicators to R&D and innovation is to capture the purposeful act that a company undertakes, in order to innovate. Thus, the input indicators measure the intentional part of the innovation process in companies, and is represented by the resources and effort, which companies spend and put into the process. There are many sources of the intentional part of an innovation process, and the input and output indicators are accordingly divided into groups representing management, employees, networks, etc. It is an important point that the input indicators should measure whether companies are working intentionally to promote innovation, and that it does not necessarily follow that this process leads to innovation. Therefore, an indicator should not be judged upon whether or not the result is certain to be innovation. Rather, it should be considered whether or not the input indicator actually measures the intentionality in the process of innovation in a company.

4.2 Baseline measurement at ex post evaluation

Emphasis is placed on ensuring baseline measurements of the efforts in order to be able to document the situation before the launch of research and innovation programmes and the situation if the programme had not been implemented, so that the effect of the research and innovation programmes can be estimated in relation to the situation where the programmes did not exist.

In this connection, the most recent research-based methods are applied by choosing advanced control groups that represent the situation if the programme had not been implemented. If the analysis includes a sufficiently large number of indicators, the propensity score matching method can be used for making

13 Gerd Meier zu Köcker, Thomas Lämmer-Gamp and Thomas Alslev Christensen: *"Let's make a perfect cluster policy and cluster programme – smart recommendation for policy makers,"* Berlin/Copenhagen 2012, VDI/VDE-IT and DASTI, October 2012, page 39-47.

14 EPISIS Report (2011), *Service innovation: Impact Analysis and Assessment Indicators.*

15 Gerd Meier zu Köcker, Thomas Lämmer-Gamp and Thomas Alslev Christensen: *"Let's make a perfect cluster policy and cluster programme – smart recommendation for policy makers,"* Berlin/Copenhagen 2012, VDI/VDE-IT and DASTI, October 2012, page 39-47.

baseline measurements, cf. principle 2. On this basis, ex post evaluations can be carried out with estimations of the effects of the programmes.

On this basis, the Danish Agency for Science, Technology and Innovation sets out key performance indicators for each research innovation programme. They can be key performance indicators in the form of both so-called outcome and impact indicators.

The assessments for the selection of indicators also follow the work from the EPISIS project mentioned above.

Tabel 4.1

Recommended input, output, outcome and impact indicators to measure the effect of research and innovation programmes

INPUT →	OUTPUT →	OUTCOME →	IMPACT
Investments	**Activities**	**Results**	**Effects**
Development	**Behaviour**		
• Public R&D expenditure in relation to GDP • Public R&D expenditure by scientific fields • Public R&D expenditure for selected strategic areas • Private R&D expenditure in relation to GDP • Private R&D by sector • Offshoring of research • Private expenditure for innovation (excl. R&D expenditure) • EU's 7th Framework Programme • Funding and grants from the European Research Council • Funding and grants from the European Institute of Innovation and Technology • External funding of university research • Flow of resources from research-funding to research-performing • R&D employees in the public sector • R&D employees in the public sector by scientific fields • R&D employees in the private sector • R&D employees in the private sector by industry • Private expenditure for innovation • Share of companies with high skilled employees • Share of academics in the workforce	• Granted PhD certificates • PhD certificates by scientific fields • Average annual growth in number of publications (15 countries most active in publishing) • Number of research publications • Number of research publications in leading scientific journals • Share of research publications with cooperation by scientific fields • Share of research publications with cooperation by type of partners • Research publications with co-authors	• Citations of scientific journals • Impact of publications with respect to scientific fields (Nordic countries) • EPO-patents and licences • Public research institutions license agreements, patent applications and spin-outs • Share of companies with innovation activities • Share of PP innovative companies • Share of PP innovative companies with innovation cooperation • The 100 most R&D active companies ("EU Industrial R&D Investment Scoreboard") • Innovations and new technologies • Start-ups	• Growth in labor productivity • Growth in Total Factor Productivity • Growth in real wages • GDP growth • Employment growth • Growth in trade turnover or gross profits
Economic investments	**Non-economic investments**	**Non-economic additionalities**	**Economic additionalities**

How to distinguish between input, output, outcome and impact indicators to measure the effect of research and innovation programmes can best be explained by looking at table 4.1 which provides an overview of the different types of indicators.

4.2.1 Outcome and impact indicators[16]

Outcome indicators deal with the newness of the innovation, the outcome indicators can be said to measure intermediate outcome of the innovation process. Therefore, outcome is about the value creation activity rather than the actual value capture of the innovation process, which is measured with impact indicators.

The impact indicators seek to measure the value that a service innovation generates and benefit the company, the customers as well as society as such. For the company, the value of the service innovation can lie in the ability for the company to sell a new service to their customers, but the value can also appear in the form of reduced costs or expenditures internally. For the customer, the value comes from the offering of an improved service compared to the existing offerings or from a service that is new to the market, hence offering the customer a larger variety of services to choose from. The latter is known from academic literature on international trade as the concept of "love of variety" (Krugman, 1979b). The increased value for society follows from the value experienced by companies and customers. Thus if a company e.g. is able to increase productivity, this is in turn valuable for society as it will have a positive impact on GDP. Furthermore, innovation by companies increases competition in the market, ensuring that the strongest companies survive.

16 EPISIS Report (2011), Service innovation: Impact Analysis and Assessment Indicators.

5. PART III – Overview key performance indicators, impact assessments and results

5.1 Results of impact assessments in Denmark

More than 17 impact evaluations of various research, innovation and education programmes have been conducted since 2008. The impact assessments have been carried out by independent researchers or organisations and were commissioned by the ministry, the agency, the research councils or by independent institutions. 12 major impact assessments of innovation policy instruments were conducted alone in 2010 and 2013[17]. Furthermore, DASTI is expected to publish 5 new impact studies in 2014. Examples of impact assessments are the following: The productivity impact of Danish business R&D and innovation investments, the Innovation Consortia Scheme, the knowledge pilot (Innovation Assistant scheme), the Incubator Programme, the Industrial PhD Scheme, the Innovation Networks Denmark Programme, EUREKA projects and business-research collaboration projects between universities and enterprises and the Danish GTS-system.

17 http://fivu.dk/en/publications/2012/central-innovation-manual-on-excellent-econometric-impact-analyses-of-innovation-policy-cim

Box 5.2

Overview over impact assessments of programmes and policies

FOCUS AREA	**CLUSTER AND NETWORK POLICIES**
Study no. 1	*The independent impact evaluation of Cluster Policy in Denmark (The Innovation Networks Denmark Programme) (DASTI 18/2011)*[18]: The programme support the establishment and running of cluster and network organisations. Among 1200 non-innovative enterprises participating in the programme, the likelihood of becoming innovative increased 300 percent compared to 1200 statistically identical enterprises not participating in the Innovation Networks Denmark infrastructure. Among R&D-active or innovative enterprises participating in the programme, the likelihood of initiating their first R&D collaboration project with a research institution increased 300 percent compared to statistically identical enterprises not participating in the programme. A new study (see study no. 18) finds that companies participating in the Innovation Network programme, on average, grow approximately 4 percentage points faster, with respect to total factor productivity, the two years following participation compared to similar non-participating companies.
FOCUS AREA	**R&D COLLABORATION PROJECTS BETWEEN BUSINESS AND RESEARCH**
Study no. 2-4	*Three independent impact evaluations (DASTI 06/2008, DASTI 03/2010, DASTI 01/2011*[19] *and Kaiser & Kuhn (2012)) of the Danish Innovation Consortium Programme* (public grants to large research collaboration projects between several enterprises and research institutions and technology institutes) show that there are statistically significant impacts for enterprises as well as for individual researchers depending on the key performance indicators to be analysed. Key performance indicators are for gross profits, individual employment, and employment in enterprises, patenting activity, salary and total factor productivity. Some of the analysis show positive and statistically significant impact for small and medium sized enterprises with respect to labour productivity, patenting activity and employment. None shows impact on total factor productivity or on large companies. One study shows positive, statistically significant impact on the level of salary of researchers at the research institutions. Gross profits increased by EUR 2.7 millions in the average enterprise participating in an innovation consortium over a period of nine years after the innovation consortium started. Enterprises did not receive public grants.
Study no. 5	*An independent impact evaluation (DASTI 17/2011) of international research and development collaboration projects (EUREKA-projects)* was conducted in 2011[20]. The impact of EUREKA-participation with respect to labour productivity, employment, turn-over and exports were analysed. The analysis shows a positive, statistically significant impact on growth rates in labour productivity, employment, turn-over and exports compared to statistically similar enterprises not participating in EUREKA-projects. EUREKA-participation also results in significantly higher growth rate in exports and employment compared to enterprises only participating in the Innovation Consortium Programme (and not in international projects).
Study no. 6	*An independent impact evaluation (DASTI 02/2011) on national research and innovation collaboration projects between enterprises and universities or GTS-institutes* (in Danish) was conducted in 2010 and 2011. Projects are projects without or with grants from public research funding bodies. More than 1,500 R&D-active enterprises engaging in one or more R&D-collaboration projects with research and technology institutions in the period 1999-2006 were compared to more than 1,500 statistically identical enterprises without collaboration found among 20,000 Danish R&D-active enterprises. The labour productivity is 9 percent higher for the average enterprise with R&D collaboration compared to statistically identical R&D-active enterprises without any collaboration in the analysed period. The analysis also looks at differences across branches, types of enterprises and types of research institutions. Impacts are higher in large enterprises than in small enterprises. Impacts are also higher in export enterprises compared to non-exporting enterprises. Finally, impacts increase with the level of skills in the enterprises.
FOCUS AREA	**EDUCATION AND ACADEMICS (CANDIDATES AND PHD'S) IN THE BUSINESS SECTOR**
Study no. 7-9	*Three independent impact studies of the Danish Industrial PhD Programme (DASTI 2007, DASTI 01/2011*[21] *and The Effect of the Industrial PhD Programme on Income and Employment 2013)* show positive, statistically significant impacts. 200-300 participating enterprises as well as for 400 participating researchers depending on the key impact indicators are analysed. The programme provides a subsidy to enterprises hiring PhD-students to work with a PhD-project. Key performance indicators are labour productivity, individual employment, and total employment in enterprises, patenting activity, individual salary and total factor productivity. The 01/2011-analysis shows positive and statistically significant impact for small and medium sized enterprises with respect to labour productivity, patenting activity and employment compared to statistically similar enterprises without Industrial PhD-projects. Patenting activity nearly doubled and employment is nearly 2 persons higher per PhD-project per year. Both analyses show positive impact for individual employment and salaries in enterprises. None shows impact on total factor productivity or on large companies. Other studies of the Industrial PhD scheme on income and employment impacts have also been conducted in 2012/2013.[22]
Study no. 10-11	*An independent impact evaluation of the Danish Knowledge Pilot (Innovation Assistant) Scheme (DASTI 04/2010*) shows that there are positive but no statistically significant impacts for enterprises. Gross profits increased EUR 156,000 in average over three years after the knowledge pilot project started. The scheme provides a subsidy to SME's hiring academics of up to EUR 20,000. Key performance indicators analysed are gross profits, total employment and survival rates of enterprises. Because of the lack of sufficient data and observations a new independent impact evaluation has been conducted. *An evaluation of the Danish Innovation Assistant Programme (Videnpilotordningen) (DASTI 12/2013*[23]*)* shows that there are positive short-term employment effects for the innovation assistants, but no statistically significant impacts for enterprises. The scheme provides a subsidy of up to EUR 20,000 for SMEs hiring university graduates. Key performance indicators analysed are gross profits, added value, return on assets, labour productivity, total employment and survival rates of enterprises. These results are confirmed by a new study (see study no. 18) that finds that companies participating in the Innovation Assistant programme, on average, grow approximately 3 percentage points faster, with respect to total factor productivity, the two years following participation compared to similar non-participating companies.
Study no. 12	*An independent study of the impact of PhD-candidates on productivity in enterprises (DASTI 2012, prepared by CEBR – Centre for Economic and Business Research at CBS, Copenhagen, 23. September 2011*) shows that the average labour productivity in enterprises with minimum one PhD-candidate is approximately 34 percent higher compared to enterprises with the same mix of educations and skills but without a PhD-candidate. The impact of PhD-candidates seems to be smaller in small enterprises than in larger enterprises. The average labour productivity difference for small enterprises with and without PhD-candidates is 11 percent. The salary of PhD-candidates is approximately 10 percent higher than the salary of non-PhD-individuals with same educational background, age and sex and working in the same type of enterprise and business sector.

18 http://fivu.dk/en/publications/2011/the-impact-of-cluster-policy-in-denmark and http://fivu.dk/en/publications/2011/innovation-network-denmark-performance-accounts-2011

19 http://fivu.dk/en/publications/2010/an-analysis-of-firm-growth-effects-of-the-danish-innovation-consortium-scheme

20 http://fivu.dk/en/publications/2011/economic-impact-of-international-research-and-innovation-cooperation

21 http://fivu.dk/en/publications/2011/analysis-of-the-industrial-phd-programme

22 http://fivu.dk/en/publications/2013/the-effect-of-the-industrial-phd-programme-on-employment-and-income

23 http://fivu.dk/en/publications/2013/an-evaluation-of-the-danish-innovation-assistant-programme-en-effektmaling-af-videnpilotordningen

Study no. 13	*The Report on 'Productivity and higher education' has been conducted by the Centre for Economic and Business Research (CEBR) for the Danish Business Research Academy (DEA) in 2010.* The effect of different types of highly-educated working capacities on the productivity (added value) in 138,372 Danish enterprises over a nine year period (from 1999 to 2007) is analysed. The analysis shows that the productivity for each individual becomes increasingly higher, the longer the person's educational background is, regardless of the field of education. Education within social sciences results in the highest individual productivity. Technical, health sciences and life-science result in a slightly lower productivity than the social sciences. One percentage point increase in the share of employees with a long-cycle higher education will cause an increase in the Gross National Product by approximately 1 percent.
Study no. 14	*An analysis of the macroeconomic benefits of attracting international students (2013)*. The Danish Ministry of Higher Education and Science has commissioned an analysis of the socioeconomic benefits of attracting international students to complete full Master's degree programmes in Denmark. The analysis has been carried out by the Danish Rational Economic Agents Model (DREAM) group. The analysis shows that attracting international students with a Bachelor's degree level of education to Denmark to complete a full Master's programme is socioeconomically beneficial. This is true both of students who are subject to fees when attending a Master's programme in Denmark and of students from other EU/EEA countries which attend Master programmes in Denmark based on financing from the Danish state. Attracting 1,000 additional international students annually results in a lasting improvement of public finances of between DKK 0.4 billion and 0.8 billion. The revenue primarily results from tax revenue generated by graduates who choose to stay in Denmark. The DREAM model is built and the calculations are made on the basis of experience with the behaviour of consumers, businesses and so on. An important assumption in these particular calculations is that the share of students which stay in Denmark after their graduation remains the same as in recent years.[24]
FOCUS AREA	**COMMERCIAL EXPLOITATION OF PUBLIC AND PRIVATE RESEARCH AND INVENTIONS**
Study no. 15	*An independent impact evaluation of the Incubator Programme (DASTI 01/2010)* shows that there are no statistically significant impacts for more than 300 enterprises and more than 300 entrepreneurs. The scheme provides public risk capital to the establishment of new knowledge intensive enterprises. Key performance indicators analysed are individual salaries, revenue, added value, total employment and survival rates of enterprises. Because of the lack of sufficient data and observations a new independent impact evaluation is conducted in 2014. The focus of the upcoming study is impacts at the level of enterprises.
Study no. 16	*Public research – effects on innovation and economic growth (2012[25])* The Danish Ministry of Higher Education and Science has commissioned an analysis of the effects on innovation and economic growth of public research. The report which is written in Danish builds on results from a number of international analyses which gives an overview of the types of contributions from publicly funded R&D to economic growth. The results are as follows: The estimated yearly benefit to the Danish economy from public investments in R&D is estimated at 20-40 percent. A DKK 1 billion R&D-investment result in growth in the Danish economy measured as gross domestic product (GDP) of DKK 1.2-1.4 billion. It must be mentioned that the causalities behind these estimates are difficult to assess. The relation between publicly funded R&D and education is a key issue in this context. Engineering, natural sciences and health sciences seem to make the most obvious types of contributions. The time elapsed from when research results are discovered and translated into industrial commercialization is estimated to vary between 6 and 20 years, depending on the research field. The period seems to have shortened over time. The report is based on three underlying reports which can be found via the links below. The first underlying report is authored by PhD Rikke Nørding Christensen, Professor Svend Erik Hougaard Jensen, CBS, Professor Keld Laursen, CBS and Professor Michael S Dahl, AAU and contains a review of Danish and international literature about the economic growth effects from publicly financed R&D. The second underlying report is authored by PhD Rikke Nørding Christensen and Professor Svend Erik Hougaard Jensen, CBS, and contains an analysis of the types of contributions from publicly financed R&D to the Danish economy from different research fields. The third underlying report is made by Senior Analyst Johan Moritz Kuhn and Senior Analyst Martin Junge, CEBR, and contains analyses of the PhD-employment, wage level and productivity in Danish firms.
FOCUS AREA	**META-EVALUATIONS**
Study no. 17	*DASTI (Innovation: Analyse og Evaluering 03/2013), "Economic impacts of Business Investments in R&D in the Nordic Countries – A microeconomic analysis"* estimates labour productivity elasticities of R&D investments. The estimated R&D labour productivity elasticities are positive and significant for the enterprises in Denmark, Finland, Norway and Sweden. Furthermore, the sizes of the elasticity are within the normal bounds as described by the literature. When comparing the R&D elasticities, it is apparent that the elasticities vary across the Nordic countries. Denmark and Sweden has the lowest R&D elasticities of 0.091 and 0.107 respectively. There is no significant difference in the elasticities of the two countries. Conversely, Norway and Finland have the highest R&D labour productivity elasticities of 0.129 and 0.167 respectively. When comparing the rate of return of the last invested euro in business R&D across the Nordic countries, it is apparent that the rates of return vary across the Nordic countries. Swedish companies have the lowest return of investments. The median enterprise in Sweden obtains a rate of return of the last invested euro in R&D of 16.4 percent. The return of R&D investments is 34.2 percent for Denmark and 22.7 percent for both Finland and Norway. A test for different return of investment shows that the estimated rate of returns of business R&D is significantly different across the Nordic countries. This result indicates that Danish enterprises realize a significantly higher marginal return of investment in business R&D compared to enterprises in Sweden, Norway and Finland. The report also shows that the results vary significantly across business sectors and size of enterprises.
Study no. 18	*The Impact on Productivity Growth of the Danish Innovation and Research Support System (forthcoming)* The Danish Agency for Science, Technology and Innovation has commissioned an analysis of the joint effect of the Danish innovation and research. The analysis is the first of its kind to perform a joint estimation of the economic impact of the Danish innovation and research programmes on companies' total factor productivity growth. The analysis compares the productivity growth of companies that received support from a programme with similar companies that did not received support. The analysis finds that companies participated in a programme, on average, grow 2.5 percentage points faster the two years following participation compared to non-participating companies. Furthermore, the analysis shows that programmes (i.a. Innovation Network, Innovation Voucher) that are designed to spur an increase in knowledge via Collaboration and Counselling and support increase participating companies' productivity growth by 2 to 3.75 percentage points. The estimation sample contains around 1,100 observations covering the period 2000 to 2011. The estimation sample is created by combining data from the InnovationDenmark database (see page 9) and worker-firm matched registry data from Statistics Denmark.

24 http://fivu.dk/en/publications/2013/analysis-of-the-macroeconomic-benefits-of-attracting-international-students

25 http://fivu.dk/en/publications/2012/public-research-2013-effects-on-innovation-and-economic-growth

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