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Tomas Åström, Cristina Rosemberg Montes, Tobias Fridholm, Anders Håkansson and Annika Zika-Viktorsson

Technopolis Sweden (Faugert & Co Utvärdering AB) and Technopolis Ltd.

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The Research Council of Norway
P.O.Box 564
NO-1327 Lysaker

Telephone: +47 22 03 70 00
Telefax: +47 22 03 70 01
post@rcn.no
www.rcn.no/english

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Summary

The impact analysis described in this report was tasked with analysing, and where possible quantifying, the Norwegian technical-industrial (TI) institutes' contribution to value creation in society both directly and indirectly. The impact analysis is part of the background material for an evaluation of the TI institutes that is conducted by an international panel of experts appointed by the Research Council of Norway (RCN). The impact analysis was carried out by Technopolis between January and May 2015.

The qualitative part of this impact analysis, which is based on web survey and interview data, illustrates that the TI institutes play an important role in providing expertise, facilities and networks to users of all types. For some companies, the institutes are said to play a very important role. In many cases, companies and different types of public-sector organisations become recurring users, and several establish long-term strategic relationships with a TI institute to ensure recurring access to its expertise and facilities. The main underlying reason for this is that users realise, or at least believe, that collaboration will increase their own competitiveness, often seen from an international perspective.

From web survey data, we find that a majority of small and medium-sized enterprises (SMEs) (52%), and more than a third of large companies (36%), agree that buying R&D services from a TI institute on commercial terms contributes to increased turnover for the company; 43 per cent of SMEs and 31 per cent of large companies agree to a positive impact on exports. Of SMEs that have collaborated with a TI institute in a publically co-funded R&D project, 41 per cent agree to a contribution to increased turnover; 28 per cent of large companies agree. 36 per cent of SMEs and 25 per cent of large companies agree to a positive impact on exports. The expected time lag between collaborating with a TI institute and economic impact materialising for the company is most commonly 2–5 years. However, the expected time lag is much shorter when companies have bought services from an institute on commercial terms (rather than collaborated in a publically co-funded R&D project).

The quantitative part of the analysis, which is based on analyses of several databases, finds that the TI institutes in the period 1997–2013 have managed to attract NOK3.4 in income from other sources for each NOK in Norwegian public funding received. However, this multiplier has been in sharp decline in the period due to a decreasing share of income from Norwegian industry and a simultaneously increasing share of income from RCN. Moreover, an econometric analysis shows that an increase in Norwegian public funding results in an increase in other funding in the future (rather than in a decrease or a replacement).

The economic impact of the TI institutes is explored through four different impact streams: (i) direct economic value creation; (ii) indirect and induced economic impact; (iii) economic value created through licensing, patenting and spin-off companies; and (iv) wider economic impact and knowledge spillover effects. The analyses estimate that, with the NOK10bn in Norwegian public funding that the TI institutes have received in the period 1997–2013, they have generated the following economic impact:[1]

- NOK37bn in the period 1997–2013 through the first two impact streams
- NOK11bn in the period 1997–2013 through the third impact stream, mainly from the turnover generated by 117 spin-off companies

[1] All NOK amounts in the summary are stated in real prices 1998-fixed.

- NOK800bn of additional turnover that in the period 2004–2013 has been generated by user companies through the fourth impact stream, in part as a result of their collaboration with TI institutes

The substantial impact created through the fourth impact stream represents 1.1 per cent of the total turnover of all Norwegian companies in the same time period. However, we judge that this large impact is not fully attributable to TI institute collaboration, and that some proportion of the increased output estimated is due to users' own qualities, probably including complementary investments. However, it is reasonable to conclude that the TI institutes have been a critical element in facilitating the estimated 1.1 per cent expansion of industry turnover within the Norwegian economy in the last decade.

In conclusion, the qualitative and quantitative sub-studies paint a coherent picture. The TI institutes play a very important role in the Norwegian innovation system, and the direct and indirect economic impact that they generate is of great importance to Norway and to Norwegian companies and public organisations.

The bibliometric analysis shows that the TI institutes are heavily involved in scientific collaboration, and that almost half of the publications have foreign co-authors. However, the level of co-publication with Norwegian companies is quite low (as is the incidence of scientific publishing in Norwegian industry is general), and only a small part of the institutes' collaboration with industry is therefore reflected in bibliometric data.

1. Introduction

1.1 Panel evaluation of the Norwegian technical-industrial research institutes

According to its statutes, one of the main tasks for the Research Council of Norway (RCN) is to "work to achieve a constructive distribution of tasks and cooperation between research institutions, and take strategic responsibility for the research institute sector".[2] RCN's five-year plan for evaluation of research institutes states three overarching objectives for such evaluations:[3]

1. To provide knowledge for the institutes own strategic development efforts,
2. To strengthen the knowledge base for the efforts of the Research Council and the ministries to develop an effective, targeted research policy, and
3. To provide a basis for assessing the design of the Research Council funding instruments.

As part of its strategic responsibility for the institute sector, RCN evaluates the research institutes, and the time has now come to evaluate the Norwegian technical-industrial research institutes (hereinafter referred to as TI institutes):

- Christian Michelsen Research AS (CMR)
- Institute for Energy Technology (IFE):
  - IFE nuclear research activities
  - IFE other research activities
- International Research Institute of Stavanger AS (IRIS)
- Norwegian Marine Technology Research Institute AS (MARINTEK)
- Norwegian Geotechnical Institute (NGI)
- NORSAR
- Northern Research Institute AS (Norut) – Norut Tromsø
- Northern Research Institute AS (Norut) – Norut Narvik
- Norwegian Computing Center (NR)
- SINTEF Energy Research AS
- SINTEF Petroleum Research AS
- SINTEF Foundation:
  - SINTEF Building and Infrastructure
  - SINTEF ICT
  - SINTEF Materials and Chemistry
  - SINTEF Technology and Society
- Tel-Tek
- Uni Research AS

2 Statutes of the Research Council of Norway.

3 «Instituttevalueringer, Overordnet plan», Norges forskningsråd, 2013.

For the purposes of the evaluation, the two largest institutes (IFE and SINTEF Foundation) have been subdivided into subunits to account for the fact that the 14 TI institutes are of very different size, meaning that the evaluation in total will assess 18 institute entities. The evaluation of the TI institutes thus encompasses institutes doing research spanning from industrial processes, materials and chemistry and ICT, to marine technology, energy, petroleum, nuclear technology, geoscience and technology and society.

The evaluation is a combination of i) an assessment of individual institutes and entities (and their particular framework conditions, strengths, weaknesses and possibilities); ii) an evaluation of technical-industrial research in Norway, including the institute sector's national and international interactions; and iii) an evaluation of the institute sector's changing framework conditions and demands. At the overall level, the evaluation embraces several important aspects of the Norwegian research system, and the future challenges and opportunities of the Norwegian TI institutes.

1.2 Supporting documentation for the evaluation

The evaluation of the TI institutes is conducted by an international panel of experts appointed by RCN, supported by a panel secretary contracted by RCN. The panel will conduct hearings with the institute entities, and does additionally have a vast amount of background material at its disposal, including:

1. Internal evaluations (self-assessments) by the institutes
2. Fact report on the institutes prepared by RCN
3. User survey
4. Impact analysis
5. Bibliometric analysis
6. Evaluation of basic and long-term research within technology conducted by RCN

RCN has procured a three-part assignment to produce items 3, 4 and 5 in this list. The assignment has been carried out by Technopolis Group in collaboration with Stiftelsen Nordisk institutt for studier av innovasjon, forskning og utdanning (NIFU) between January and May 2015. The assignment, led by Tomas Åström of Technopolis, has been carried out as three subprojects. The impact analysis subproject has been carried out by a team consisting of Tomas Åström, Cristina Rosemberg Montes, Tobias Fridholm, Anders Håkansson and Annika Zika-Viktorsson. The team was supported by Oliver Cassagneau-Francis and Carolina Jonsson. The subproject was led by Tomas Åström and quality controlled by Erik Arnold. This report summarises the findings of the impact analysis; the user survey and bibliometric analysis subprojects are presented in separate reports. To complete the impact picture, a summary of the bibliometric analysis subproject, authored by Dag W. Aksnes of NIFU, is included in Chapter 4 of this report.

1.3 The impact analysis assignment

The impact analysis has been tasked with analysing, and where possible quantifying, impact in terms of:

- Direct economic value creation
- Value creation in other sectors of society as a result of the institutes' operations
- Economic value created through licensing, patenting, spin-off companies etc.
- Spillover effects to industry and public administration from the institutes' R&D activities

The impact analysis is thus to shed light on the institutes' contribution to value creation in society both directly and indirectly, in the form of economic value (contribution to the gross domestic product (GDP)), employment, development of competence, implementation of innovations (e.g. through production or dissemination of new technology), welfare etc.

In contrast to the user survey and the bibliometric analysis subprojects, the impact analysis subproject has not been required to report at the level of institute entities, only for the TI institutes as a group.

1.4 Methodologies and data sources

In practice, this report merges the findings of three impact sub-studies that have been conducted using very dissimilar methodologies and data sources:

1. Qualitative impact sub-study
2. Economic impact sub-study
3. Bibliometric analysis subproject

The results on scientific impact that are briefly recounted in this report are in essence the summary of the separately reported bibliometric analysis subproject, for which reason the methodologies and data sources are not described herein.

1.4.1 Qualitative impact sub-study

The qualitative impact sub-study employs the following terminology:

- A **partner** is a private or public organisation cooperating with a TI institute in a publically co-funded R&D project, e.g. from RCN and the EU's Framework Programme (FP)
- A **client** is a private or public organisation that buys services from a TI institute on commercial terms
- **User** is a generic term for a partner or a client
- A **Norwegian** or **foreign** user is defined based on the formal location of the legal entity that collaborated with the institute (i.e. if a US corporation collaborated with an institute through its Norwegian-based subsidiary, the user is considered Norwegian)
- A **large company** is a private company with 251 or more employees worldwide
- An **SME** (small and medium-sized enterprise) is a private company with 250 employees or less worldwide (a simplified SME definition)
- An **HEI** (higher education institution) is a university or a university college
- A **research institute** is a (Norwegian or foreign) research institute; in the case of Norwegian research institutes, only institutes from other arenas than the TI institutes are included in this terminology
- The **private sector** refers to private companies of any size
- The **public sector** includes government agencies, counties, municipalities, universities, university colleges, research institutes and public enterprises (including health trusts). In many figures, HEIs and research institutes are presented as user categories of their own. In these cases the term public sector refers to the remaining types of organisations of the definition[4]

[4] We are aware of the existence of private HEIs and research institutes. Since these in practice function as their public counterparts, we have for analytical reasons included them in the public category.

The qualitative impact sub-study was conducted through interviews and a web survey, which were both directed to broad samples of institute users. Both interviewees and web survey respondents were selected from three main sources:

- Lists of key clients that the institutes shared with RCN as part of the self-assessment reports that they were required to provide for the panel evaluation[5]
- A subset of RCN's data warehouse, presenting projects finished in 2005 or later and where one or more of the institutes had been partners
- A subset of the E-Corda database of projects in the EU's Seventh Framework Programme for Research (FP7) finished in 2010 or later in which one or more of the institutes had been partners

In addition, we carried out desktop studies of RCN's fact report prepared for the panel, the 18 institutes' self-assessment reports, RCN's annual reports on the TI institutes, the institutes' websites etc.

For the interviews and the web survey, we used the lists of key clients in the self-assessment reports to identify clients and the other two data sources to identify partners. As expected, it soon became clear that many of the key clients were also significant partners. Since a partner relation is likely to be more in depth than a client relation (which was also the message these users generally conveyed in the interviews), we usually treated these users as partners, even though we investigated the client relation as well.

The interviews and the web survey were mainly conducted to provide empirical data for the user survey subproject, but they were simultaneously used to generate data for the qualitative impact sub-study of the impact analysis subproject presented herein. The outcome of the ambitious data acquisition of the interviews and the web survey are consequently only to a very limited extent presented in this report.

1.4.1.1 Web survey

The invitations to the web survey were e-mailed to 2,002 individuals in user organisations and the survey was open from 9 March to 30 March 2015. The e-mail list included:

- All listed key clients (not only Norwegian clients)
- Project leaders of all RCN projects finished in 2005 or later and where at least one of the TI institutes had been a partner (all Norwegian partners)[6]
- Partners of all FP7 projects finished in 2010 or later in which a TI institute had participated and where the partner had had at least 5 per cent of the total project budget. This threshold was implemented to eliminate partners with only marginal (or no) expected experience of a TI institute. However, CMR and Tel-Tek have had so few FP7 partners that we did not implement the threshold for their partners (mostly foreign partners)

No e-mail address was included more than once; multiple appearances were eliminated through randomisation, meaning that individuals who had been contact persons in several institute relations only were asked to respond regarding one of these relations. However, several individuals per organisation could receive invitations to the survey.

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5 The institutes were asked to list their "most important" clients, meaning that they provided a selection of the client base.

6 We only included project leaders because RCN's data warehouse does not include e-mail addresses to other partners. Projects led by the TI institutes were excluded altogether.

The first invitation to respond to the survey was sent on 9 March, with reminders 16 March and 24 March. The last reminder was accompanied by a separate e-mail from RCN that encouraged recipients to respond. The final response rate was 26 per cent, or 518 respondents. Another 53 respondents only provided background information (which type of organisation they represented etc.) but did not respond to a single question that directly concerned the impact analysis or the user survey. Table 1 summarises response rates per respondent category.

Table 1 Web survey response rates per sample category.

Sample category	Selection	Responses	Response rate
Key clients	361	141	39%
Partners in RCN projects	433	169	39%
Partners in FP7 projects	1,208	208	17%
All	**2,002**	**518**	**26%**

As already mentioned, the key client category was intended to capture clients, while the RCN and FP7 categories were expected to generate partner responses. The respondents were asked to classify their organisation as client or partner. Somewhat to our surprise, 81 (57%) of the key clients defined themselves as “mainly partners”. Similarly, 33 (20%) respondents in the RCN partner category and 3 (1%) in the FP7 category defined themselves as “mainly clients”. As already mentioned, respondents that considered their organisation “client and partner in roughly equal proportions”, were classified as partners.

Table 2 shows the distribution of respondents in the client and partner categories. The outcome was 422 partner responses and 96 client responses; in other words a significant dominance by the former. A large majority of the responding clients are Norwegian, while the responding partners are rather equally distributed between Norwegian and foreign partners. Clients and partners received slightly different sets of questions, although most of the questions were identical for both categories. The part of the web survey that concerns user satisfaction aspects is reported in the user survey.

Table 2 Distribution of web survey respondents into categories and nationality.

Category	Norwegian	Foreign	All
Partners	219	203	**422**
Clients	81	15	**96**
All	**300**	**218**	**518**

Respondents were also asked to classify their organisation into type; Table 3 summarises the distribution into user categories. Large companies constitute the largest category, followed by HEIs and SMEs. Most of the respondents from research institutes are foreign, and the Norwegian ones are all from institutes in other arenas (than the TI arena). The public sector provided the smallest number of respondents. The large companies, SMEs and users in the public sector are predominantly Norwegian, while the university respondents are equally split between Norwegian and foreign.

Table 3 Distribution of web survey respondents on user categories.

User category	Norwegian	Foreign	All
Large companies	108	44	**152**
SMEs	72	42	**114**
HEIs	61	57	**118**
Research institutes	23	59	**82**
Public sector	36	16	**52**
All	**300**	**218**	**518**

Table 4 shows how the respondents are distributed on institute units. IFE's respondents cannot be separated into the two units (nuclear and other activities), since the data sources do not include this information (the two units are one and the same legal entity). For the same reason, we are unable to separate the different units of the SINTEF Foundation for the FP7 partners, which means that these four units have almost only Norwegian respondents (for which the subdivision is available) and a large number of foreign respondents in common for the SINTEF Foundation. Several institutes, mainly the smaller ones, have very few, or no, foreign respondents. The distribution of respondents on institute units are of limited relevance for the qualitative impact sub-study presented herein (but of great importance for the user survey where data is presented at the level of individual institute entities).

Table 4 Distribution of web survey respondents on TI institute units.

Research institute	Norwegian	Foreign	All
CMR	21	3	**24**
IFE nuclear + IFE other	38	19	**57**
IRIS	18	2	**20**
MARINTEK	16	15	**31**
NGI	15	8	**23**
NORSAR	3	15	**18**
Norut Tromsø	6	4	**10**
Norut Narvik	9	0	**9**
NR	19	7	**26**
SINTEF Energy	14	19	**33**
SINTEF Petroleum	10	9	**19**
SINTEF Building and Infrastructure	15	0	**15**
SINTEF ICT	20	1	**21**
SINTEF Materials and Chemistry	44	0	**44**
SINTEF Technology and Society	16	0	**16**
SINTEF Foundation	12	111	**123**
Tel-Tek	11	1	**12**
Uni Research	13	4	**17**
All	**300**	**218**	**518**

The relatively high share of non-respondents is problematic and may indicate that the results are biased. In order to verify the results, we attempted to perform a non-response follow-up. An e-mail was sent to 100 individuals randomly selected among the approximately 1,500 non-responders, asking them to briefly state why they did not respond to the survey and to answer two of the most central questions in the user survey with a simple number between one and five. However, the feedback on these e-mail invitations, a mere twelve responses, neither provided a useful result, nor any hope that reminders would render an acceptable number of responses.

We have very limited background information on our respondents and non-respondents, which prevents us from conducting a proper non-response analysis. However, the response rates provided in Table 1 gives some indications on what may have been the cause of the relatively low overall response rate. First of all, we consider response rates of 39 per cent for key clients and partners in RCN projects to be relatively high, and quite on par with other similar surveys. The low response rate for FP7 partners probably has several reasons. One reason may be that since most of them are foreign, they have limited interest in participating in a Norwegian survey. Another reason may be the well-known fact that the project contact persons in E-Corda are quite often not researchers, but managers or administrators who lack insight into the relations with the institutes. The relatively low response rate from FP7 partners is therefore not surprising.

However, as we shall later see, survey results clearly indicate that the vast majority of client respondents are repeat clients (of the same TI institute). This means that the clients are a positive selection, i.e. most of them must have had sufficiently positive experiences with the institute in the past, or they would not have come back for more. Moreover, the majority of clients were provided in the institutes' self-assessment reports, and we assume that they have not listed clients that they know have been dissatisfied.[7]

Survey responses also show that a majority of partner respondents are repeat collaborators, even though the degree of recurring collaboration is less pronounced than for clients. It is also likely that dissatisfied partners are less interested in contributing to a user survey than satisfied ones (which in part may explain the low response rate for FP7 partners), meaning that it is reasonable to assume that the partner respondents are also positively inclined.

This means that there is a positive bias among survey respondents, and there is consequently reason to interpret survey results bearing this in mind. On the other hand, the recurring collaborators that dominate the respondents ought to be quite knowledgeable on the institutes' strong and weak points, meaning that their responses ought to be well founded. In summary, we cannot say that the respondents are representative of all TI institutes' users.

1.4.1.2 Interviews

In sampling the interviewees, we categorised users into three categories:

1. Whether the user was Norwegian or foreign-based
2. Whether the user's relation with the institute was mainly that of a client or that of a partner
3. Whether the user belonged to the private or the public sector

Given that around 80 per cent of the institutes' revenue is domestic, Norwegian users had to be well represented in the interviews. The views of foreign users are nevertheless important, since they are likely to hold the key to how the institutes can increase their international competitiveness. The client category is particularly relevant since buyers of commercial services are generally more demanding and ready to turn to another supplier if they feel that they do not get value for money. Finally, organisations in the Norwegian public administration are important in light of the institutes' mission to provide applied R&D services also to public entities and to society at large. We also tried to maintain a fair balance between clients and partners from different industry sectors and technical domains (for several institutes we otherwise risked ending up with too many interviewees from the oil and gas sector). Although this to some extent implicates the risk of introducing bias by giving more weight to less important sectors, we found that a diversity of views was more important. For each institute entity we made sure not to miss its key user sectors or technical domains.

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[7] It is possible that the addresses from RCN's data warehouse and E-Corda include the some dissatisfied clients; 34 percent of client responses are from addresses from RCN's data warehouse and 4 percent from E-Corda.

Just as for the web survey, we created a threshold for FP7 partners to increase the likelihood that the potential interviewees would have sufficient knowledge about the institute in question. For the interviews, the threshold used was that both the institute and the partner should have had at least 10 per cent each of the total project budget. We note that this threshold resulted in almost all interviewees having participated in projects where either the institute or the interviewee's organisation had been project coordinator.

We conducted 79 unique interviews, distributed on user categories as shown in Table 5. The distribution into categories is not entirely as planned; most notably the foreign respondents are fewer than intended. The main reason is that there were fewer foreign organisations than expected among the key clients. In addition, these were concentrated to a minority of the institutes and to certain industry sectors (mainly oil and gas). Although many interviewees had experience of collaborating with more than one TI institute, each interview concerned one institute only.

Table 5 Distribution of interviewees on user categories.

User category	Norwegian	Foreign	Total
Private clients	18	9	**27**
Public clients	13	3	**16**
Private partners	19	5	**24**
Public partners	9	3	**12**
All	**59**	**20**	**79**

The interviews typically lasted for half an hour and covered an overall description of the collaboration, user satisfaction with the institute in a number of dimensions, as well as the user's suggestions on how the institute and the TI institutes as a group could develop their services in the future. The interviews also concerned users' rationale for collaborating with the institute and what results and impact the collaborations had already had, or were expected to have, on users. The questions on user satisfaction were intended for the parallel user survey and the responses to these questions are not discussed in this report. The interview guide was adapted to tailor questions to different user categories.

1.4.2 Economic impact sub-study

For logical reasons, the methodological considerations of the economic impact sub-study are integrated into Chapter 3, and for reasons of readability, much of the methodological details are provided in Appendix A. The data sources used include:

- NIFU's R&D statistics bank to access information from previous RCN annual reports on the TI institutes
- An extract from RCN's data warehouse with all RCN projects wherein a company participated to construct both a group of users and a control group of companies that have not participated with the institutes (**non-users**, mainly large companies)
- RCN's SkatteFUNN database, also to construct a group of users and a control group of non-users (mainly small companies)[8]
- Eniro's database with complete profit and loss accounts and balance sheets for Norwegian companies (supplied by RCN with permission from Eniro)

[8] RCN and Innovation Norway jointly administer the SkatteFUNN scheme that may give a company a tax reduction for its R&D costs; large companies may get up to 18% tax reduction and SMEs up to 20%.

- EPO Worldwide Patent Statistical Database (PATSTAT) to access information on the TI institutes' patenting

1.5 Acknowledgements

We would like to acknowledge the fact that the team has received extensive support by RCN staff, and we are particularly grateful for the time invested by interviewees and survey respondents.

2. Qualitative impact

This chapter reports on the impact part of the web survey and the interviews, and it is intended to complement the economic and scientific impact described in subsequent chapters.

We have elected to present the empirical data for clients and partners separately, based on the hypothesis that impact is quite different for these two categories, and that it develops along different time scales. The reason for this argument is that as clients, users buy services from a TI institute on commercial premises, i.e. at full cost, to satisfy a specific need (problem solving) and they generally expect to be able to use the results of the services in the short term. As partners, where users pay for only part of the work of a TI institute, users often collaborate with other organisations to develop new knowledge that may possibly be used to improve products and processes in the future. Given this more probing mind-set, the expectations for commercial benefits are vaguer and longer term. This hypothesis is based on the experiences of a large number of previous impact assessments and impact evaluations, so we already know that it is in general well founded. At the end of this chapter, we will sum up whether the empirical data of this sub-study supports the hypothesis or not.

2.1 Clients

The number of web survey responses from research institutes and HEIs acting as clients are so few that their responses are not analysed in the following (but they are separately reported in the subsequent section on partners). There are no responses at all from foreign SMEs, which in part may be explained by the fact that the TI institutes were instructed to provide names and contact information to their “most important” clients, meaning that it is quite natural that very few research institutes, HEIs and foreign SMEs were provided. Moreover, institutes and HEIs seldom buy R&D services from (other) research institutes and instead usually collaborate as partners. For the three respondent categories analysed, there are few significant differences between the responses of Norwegian and foreign clients, for which reason the responses are reported together. In the few instances where there are significant differences, they are commented upon in the text.

As mentioned towards the end of Section 1.4.1.1, the vast majority of clients are repeat clients (of the same TI institute), see Figure 1. Private companies are the most common repeat clients, and SMEs are the most faithful. The respondents are thus a positive selection, since most of them obviously must have had sufficiently positive experiences with the institute in the past, or they would not have become repeat clients. Moreover, most client e-mail addresses were provided by the institutes themselves. There is consequently reason to interpret the client responses keeping in mind that they likely include precious few dissatisfied clients.

Clients’ rationale for buying R&D services from a TI institute are summarised in Figure 2. In this and subsequent figures of the same type, a Likert-type scale has been used to get respondents to rate to what extent they agree with statements on the following scale:

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

Various commercially oriented statements only apply to private companies, thus explaining why responses to some statement are missing for public sector actors.

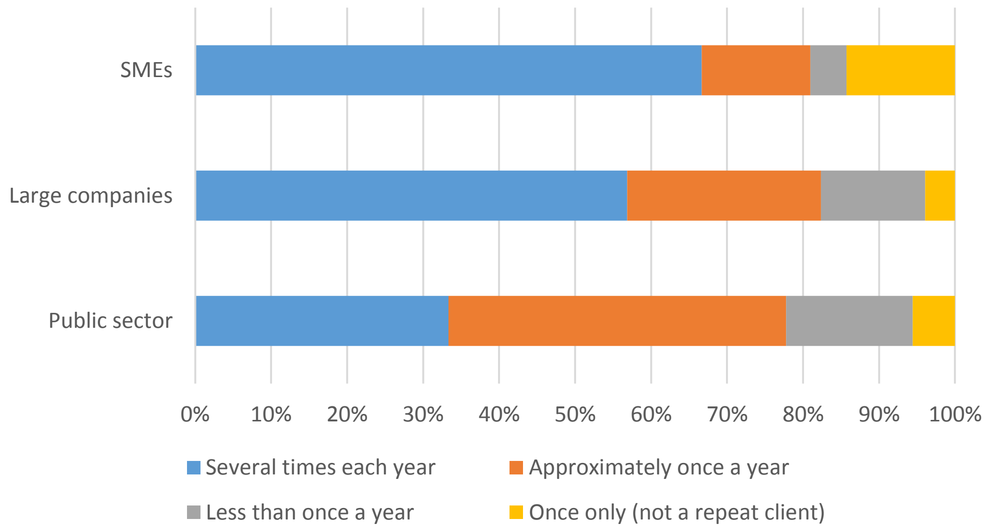

Figure 1 The frequency with which the respondent's organisation has bought R&D services from the institute. Source: Web survey.

Figure 2 illustrates that access to scientific or technical expertise is by far the most common reason for buying R&D services from a TI institute, regardless of whether the respondent represents an SME, a large company or a public sector organisation. Access to measurement and testing facilities and analysis software are other important reasons. All respondent categories seek access to networks of R&D providers (institutes and HEIs) and partners for future R&D proposals, and it is worth noting that large Norwegian companies are considerably more interested in these aspects than foreign ones, which seems natural given a general affinity for preferring collaboration partners from your own country. Public sector organisations are considerably more interested in training than companies.

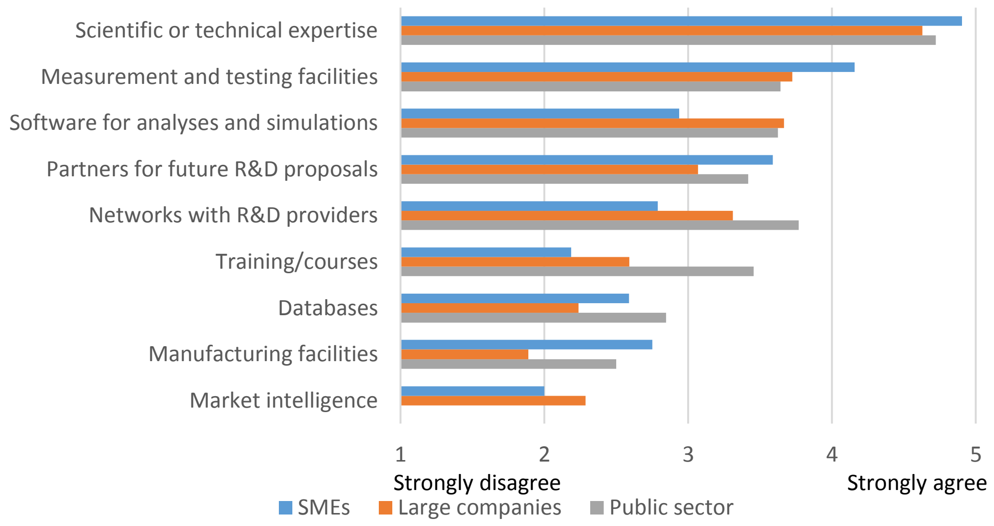

Figure 2 Rationale for buying R&D services from the institute. All statements were preceded with "Access to…". Source: Web survey.[9]

Whereas Figure 2 shows the rationale for buying services, Figure 3 illustrates the intermediate impact of the purchase (or in most cases several purchases; cf. Figure 1). The highest rated impact, improved scientific or technical skills, illustrates that the institute's expertise has been successfully transferred to the client, just as intended. Interview statements provide examples of different forms of impact of buying services from a TI institute:

> *The services we buy are absolutely critical for our product development. (Norwegian SME)*
>
> *Assignments contribute to new ideas and new ways of thinking that are important for innovation, but this is mutual, the institute also benefits from collaborating with us. (Norwegian SME)*
>
> *Recurring assignments give us access to competence that we cannot afford to have in house. (Large Norwegian company)*
>
> *The importance of our collaboration is enormous. Full-scale tests are a vital part of our product development and account for a third of development costs. When we engage the institute, we know that we get high-quality services. (Large foreign company)*

9 Statements have been abbreviated in figures to enhance readability.

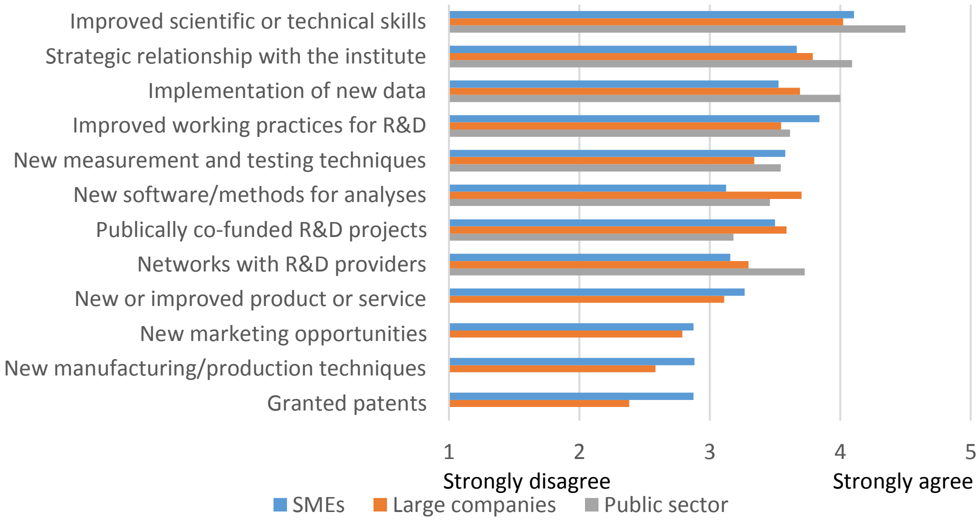

Figure 3 The extent to which buying R&D services from the institute has contributed to intermediate impact for the organisation. Source: Web survey.

Figure 3 also shows that most clients have formed a long-term strategic relationship with a TI institute to achieve some form of continuous access to its expertise and facilities. The relationship has to a significant extent led to use and implementation of new data, measurement and testing techniques, analysis software etc., and, perhaps most importantly, to improved collaborative working practices when it comes to R&D. Several interviewees representing both Norwegian SMEs and large companies also highlight the importance of expanded networks:

> *We hope that our collaboration eventually will yield profit, otherwise we would not have started collaborating. However, our main rationale is expanded networks and international exposure. (Norwegian SME)*

> *Collaboration has expanded our networks with large foreign companies. (Large Norwegian company)*

Moreover, the figure illustrates that impact of more immediate commercial nature appears to be somewhat difficult to grasp, as the statements on new or improved products or services, new marketing opportunities, and granted patents are not rated as high as one perhaps might have expected. When it comes to patents several company interviewees nevertheless explain that they often elect not to apply for patents to keep inventions to themselves.

While interviewees mainly provide positive accounts, there is also room for improvement:

> *The interface between research and our operative reality is difficult. We lack the academic competence, and the institute sometimes lacks insight into our operative realities. (Norwegian subsidiary of large multinational corporation)*

Whereas the impact reported in Figure 3 may be regarded as intermediate, Figure 4 illustrates impact in various dimensions in the economic realm. Company respondents, and in particular those representing SMEs, to a notable degree agree to increased international competitiveness, which is presumably part of the reason for increases in turnover, to a large extent on foreign markets. Another way of presenting the very same survey data, is that 52 per cent of SME respondents strongly agree or agree to the statement that buying R&D services from the institute has contributed to, or is expected to contribute to, increased turnover (no respondent fully disagrees); 36 per cent of large company respondents strongly agree or agree. By the same token, 43 per cent of SME respondents and 31 per cent of large company respondents strongly agree or agree to a positive contribution to exports. An example of an interview account:

> *The institute's contribution has been important in the development of marine engines of which we have sold a large number. This has also been very good business for Norway Ltd. (Norwegian subsidiary of large multinational corporation)*

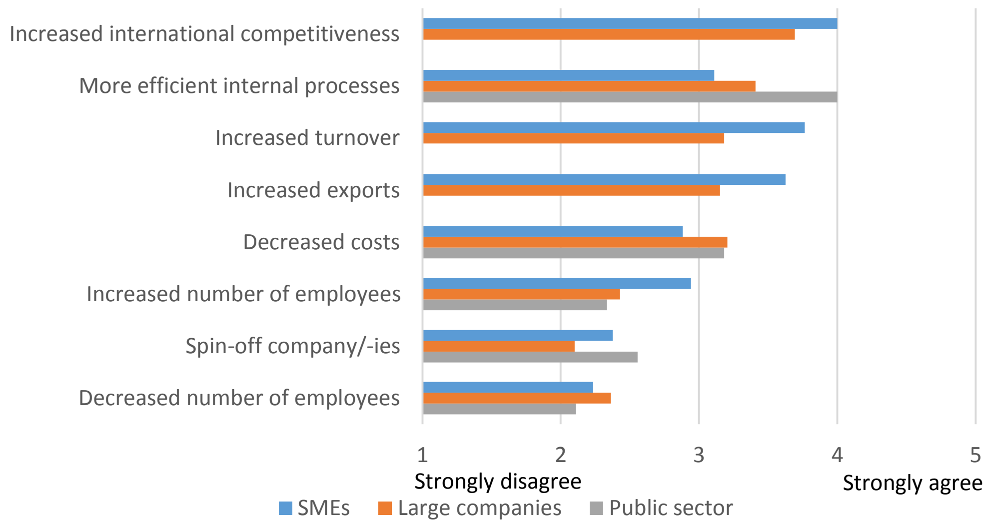

Figure 4 The extent to which buying R&D services from the institute has contributed to, or is expected to contribute to, economic impact for the organisation. Source: Web survey.

All respondent categories report on more efficient internal processes, with the strongest responses from public sector respondents. Several interviewees representing Norwegian government agencies explain that assignments have impacted national regulations, for example for road construction, rail maintenance and oil extraction. Internal efficiency gains may perhaps in part explain why few respondents see a notable impact on the number of employees.

No respondent in any category strongly agree to a spin-off company having resulted, and only four respondents (5%) agree. Thus, some new companies may have been spun off, but it seems like the attribution to the R&D services bought is not clear-cut.

The expected time lag between buying R&D services from a TI institute and economic impact materialising for the organisation is summarised in Figure 5. For most companies, 2–5 years seems to be the most common, which of course is a message to readers of this report; even though, as stated in the hypothesis at the beginning of this chapter, clients buy services that they generally expect to be able to use in the short term, it generally takes many years for economic impact to materialise. It is also noteworthy that SMEs tend to be in more of a hurry than larger companies, which is consistent with findings in a multitude of previous impact assessments and impact evaluations; SMEs tend to seek help to solve shorter-term problems, whereas larger companies tend to have a longer-term view (notwithstanding the different time perspectives between clients and partners alluded to in the hypothesis). The considerably shorter time lag for public sector organisations may be explained by R&D results presumably mainly being implemented as more efficient internal processes and regulations (as mentioned above), rather than in products or services sold to others, as one would expect for companies.

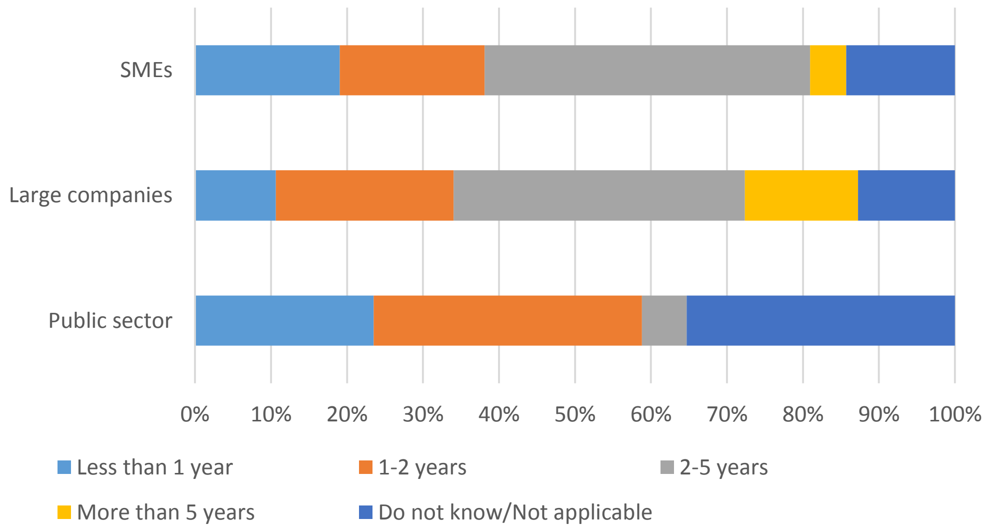

Figure 5 The expected time lag between buying R&D services from the institute and economic benefits materialising for the organisation. Source: Web survey.

When it comes to economic impact, this is as far as we get with the empirical data from the web survey and the interviews (which admittedly focused more on user satisfaction than on impact). However, we return to impact on companies that have collaborated with a TI institute (as clients or as partners) in Section 3.5, where we attempt to quantify increases in turnover and productivity.

2.2 Partners

In the previous section on clients, it was noted that the vast majority of respondents were repeat, and presumably positively inclined, users. As Figure 6 shows, there is reason to argue along the same lines for responses from partners, although the share of respondents who have only a single experience of a TI institute is considerably larger among partners. Having said that, in all respondent categories the majority have collaborated with the TI institute more than once. On balance, a certain degree of healthy scepticism towards the answers may be warranted also for partners.

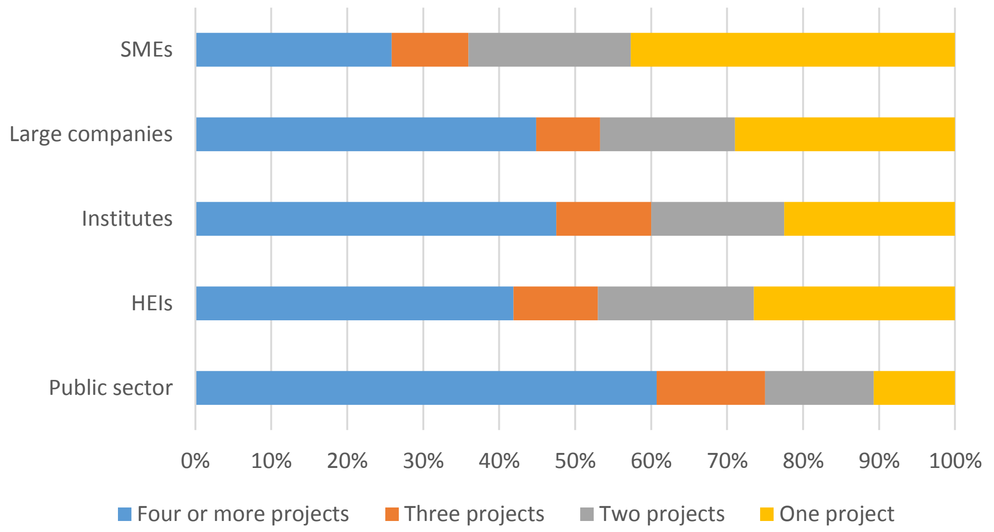

Figure 6 The number of projects in which the respondent's organisation has collaborated with the institute. Source: Web survey.

Figure 7 shows partners' rationale for collaborating with a TI institute in an RCN or an FP7 project. With the previous section on clients in fresh memory, it should be noted that while this "rationale figure" looks awfully similar to its client sibling, only six statements are identical, and the order in which they are ranked varies notably. (The same applies to the subsequent figures on impact.)

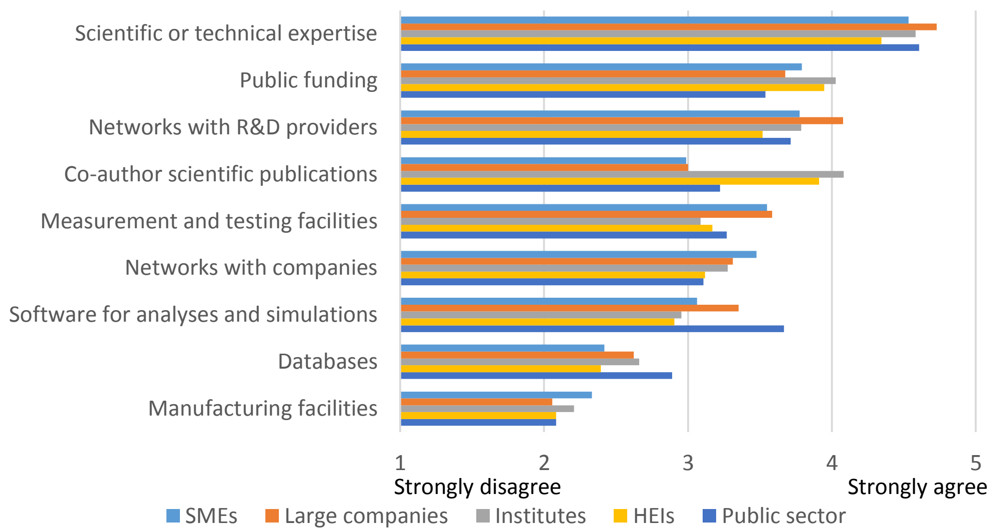

Figure 7 Rationale for collaborating with the institute in R&D projects. All statements were preceded with "Access to…". Source: Web survey.

Nevertheless, access to scientific or technical expertise is by far the most common rationale also for partners. In fact, the six statements that are common to both client and partner surveys are rated remarkably similarly, with the only notable difference being that networking with R&D providers is rated higher when companies (regardless of size) are partners. For partners, access to public funding is – of course – a strong motivator, as is scientific publications, particularly for institutes and HEIs. Unsurprisingly, the results confirm the findings of a previous study on Norwegian organisations' motives for participating the FPs.[10] The survey results reveal no noteworthy differences between Norwegian and foreign partners' rationale for collaboration.

Figure 8 illustrates the intermediate impact of collaboration with a TI institute on companies. The nine statements that are the same for client and partner surveys to companies are once again rated similarly, but for SMEs there are a couple of notable differences. SMEs rate impact in terms of patents and new measurement and testing techniques higher when they are clients. Patents are nevertheless obviously not very common in either role and for companies of any size; impact of collaborating in publically co-funded R&D projects is for the most part not that tangible, as effectively illustrated by Figure 8.

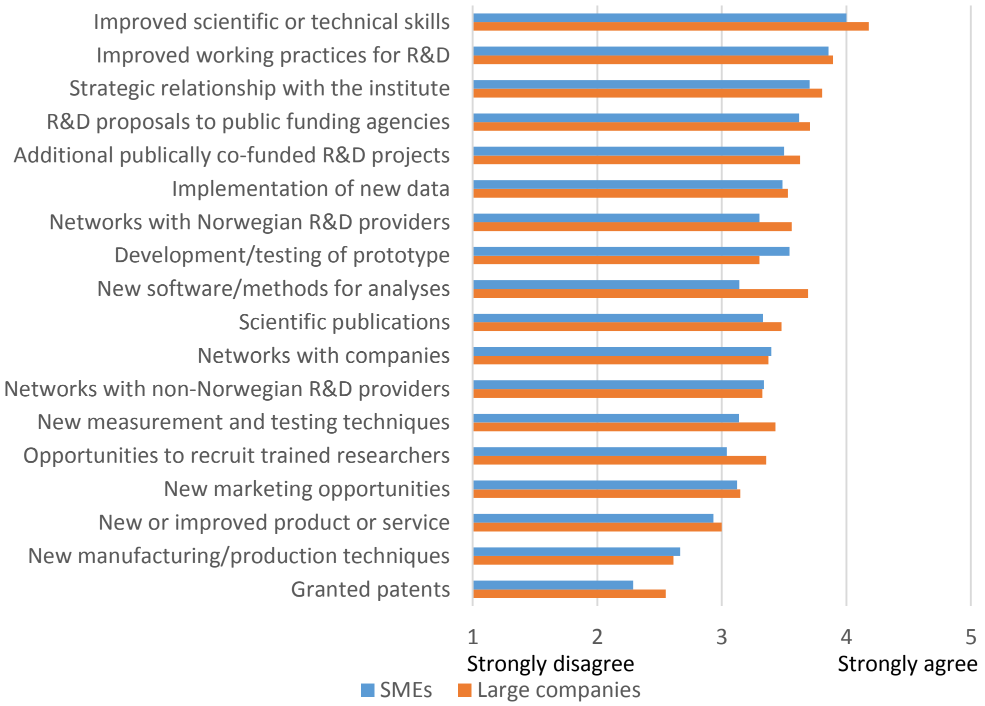

Figure 8 The extent to which collaborating with the institute in R&D projects has contributed to intermediate impact for the company. Source: Web survey.

There are some interesting differences between Norwegian and foreign respondents. Norwegian SMEs see considerably stronger impact in terms of new measurement and testing techniques, opportunities for recruitment of trained researchers, and commercialisation of new or improved products or services than their foreign counterparts. Large Norwegian companies also see notably stronger impact in terms of recruitment of researchers, and Norwegian public organisations greater benefits as regards establishment of long-term strategic relationships with TI institutes. These observations suggest that there are indeed grounds a proximity argument for collaboration in R&D. Interview statements provide enlightening examples of intermediate impact for both Norwegian and foreign companies:

> *We buy a scientific approach to a problem. (Norwegian SME)*

[10] T. Åström, T. Jansson, G. Melin, A. Håkansson, P. Boekholt and E. Arnold, "On motives for participation in the Framework Programme", Norwegian Ministry for Education and Research, 2012.

The Scandinavian market is most interesting to us, and by collaborating with the institute we get high visibility on this market. (Foreign SME)

The competence development has been considerable. By working together, you learn a lot. (Norwegian subsidiary of large multinational corporation)

Collaboration gives us a knowledge advantage that makes us more competitive, meaning that we will eventually make money. (Large Norwegian company)

Alongside expected commercial impact, we have an explicit strategy to be active project partners to allow our employees to learn, and to get new ideas and general intellectual stimulus. (Norwegian subsidiary of large multinational corporation)

The institute has capacity and competence to dig deep into issues that we don't have time with ourselves. (Large foreign company)

Figure 9 depicts intermediate impact on institutes, HEIs and other public sector organisations (with four statements less than for companies). Comparing with Figure 8, we find that research institutes, HEIs and other public sector organisations experience greater impact than companies in terms of scientific publications, R&D proposals and additional R&D projects, which is to be expected. Interestingly, other public sector (than institutes and HEIs) see significantly greater impact in terms of networking with R&D providers than all other categories, presumably because they previously had the least developed networks in that respect.

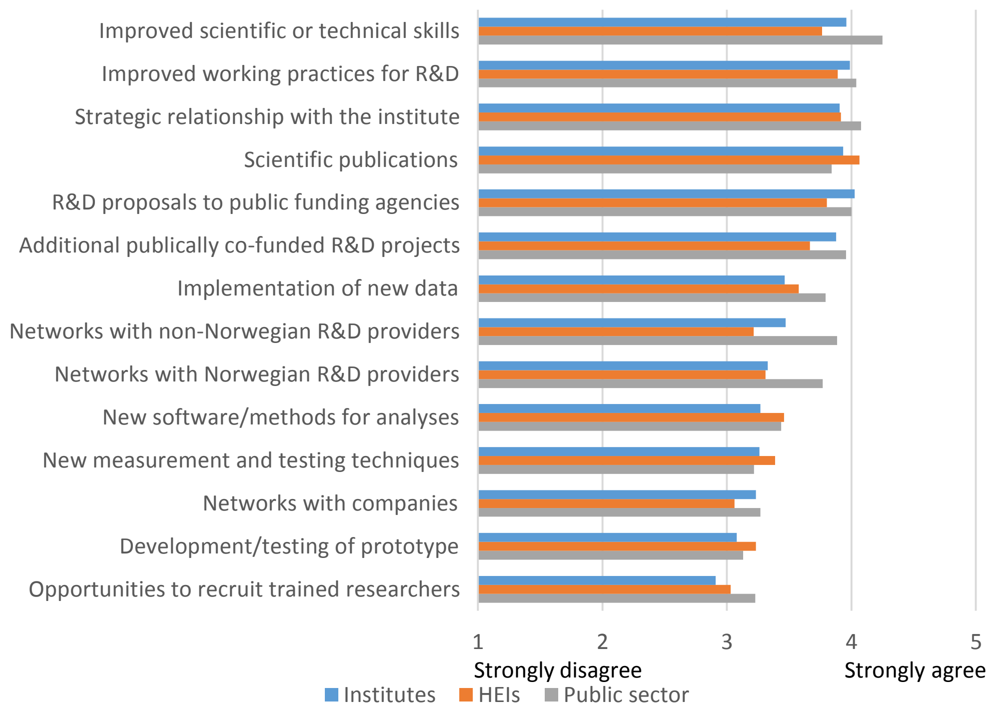

Figure 9 The extent to which collaborating with the institute in R&D projects has contributed to intermediate impact for the organisation. Source: Web survey.

Moving on to economic impact, Figure 10 illustrates that the economic impact, or the expectations of such impact, are not very pronounced. For large companies, the ratings are pretty much the same for all statements regardless of whether they are clients or partners, but SMEs see notably greater impact in terms of increased international competitiveness, turnover and exports when they are clients, which seems natural (0.5–0.6 higher rating, which is a lot).

Still, 41 per cent of SME respondents strongly agree or agree to the statement that collaborating with the institute as partners has contributed to, or is expected to contribute to, increased turnover; 28 per cent of large company respondents strongly agree or agree. On the same note, 36 per cent of SME respondents and 25 per cent of large company respondents strongly agree or agree to a positive contribution to exports. All four percentages are notably lower when companies are partners (cf. Section 2.1). There are some noteworthy differences between Norwegian and foreign companies. Norwegian SMEs see notably higher impact in terms of increased exports than foreign SMEs, and large Norwegian companies see more of decreased costs and decreased number of employees than foreign ones.

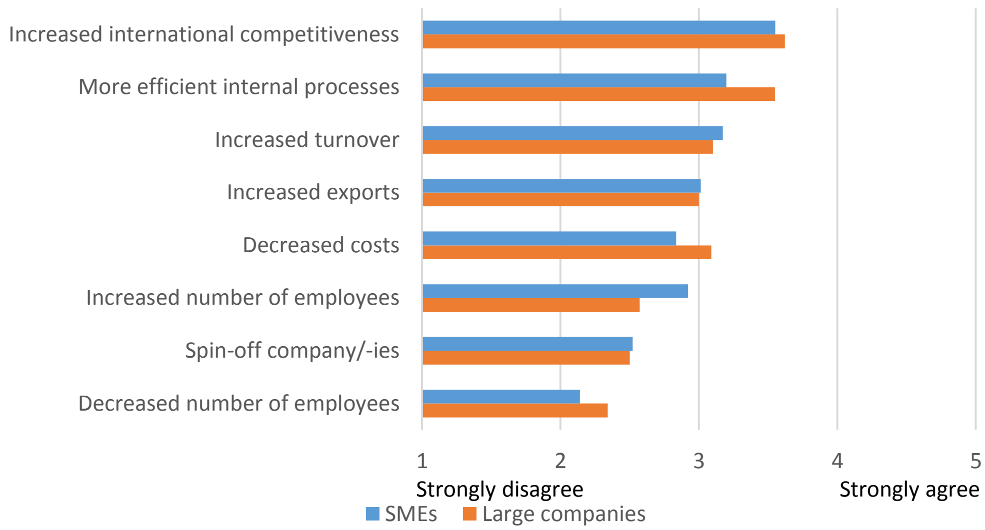

Figure 10 The extent to which collaborating with the institute in R&D projects has contributed to, or is expected to contribute to, economic impact for the company. Source: Web survey.

Figure 11 shows that the impact on research institutes and HEIs in the economic realm is quite small, except for more efficient internal processes, where there appears to be a moderate impact. In contrast, other public sector organisations experience significantly greater impact on internal processes and decreased costs. Overall, the differences between being client and partner appears to be marginal for other public sector organisations (cf. Figure 4).

To illustrate economic impact, we may look at some examples from interviews:

> *We have been able to market ourselves as a high-quality producer; there is no doubt that we sell more due to our collaboration with the institute. (Norwegian subsidiary of large multinational corporation)*

> *We expect the project to lead to both cheaper and better processes, and in the end cheaper and better construction projects. (Norwegian subsidiary of large multinational corporation)*

> *The institute developed a very powerful tool to analyse and visualise meteorological data. (Norwegian government agency)*

> *The project resulted in a unique model to quantify large fish stocks that is useful for management of natural resources. (Norwegian institute in other arena)*

Four respondents strongly agree (two from SMEs, one from an institute and one from an HEI) – and another 26 respondents agree (in total 30 or 8%) – that their collaboration with a TI institute as partner has contributed to, or is expected to contribute to, a spin-off company. Although this is potentially a very positive outcome, one may suspect that a substantial share of these responses refer to expectations rather than new companies already having been established; even so, it seems reasonable to assume that some new companies indeed have been established. However, a major unknown of course lies in the attribution of collaboration to the establishment of a spin-off company. Moreover, we do not know whether the spin-off companies that respondents have in mind are ones established by (former) employees of a TI institute or of the respondents' organisations, or a combination.

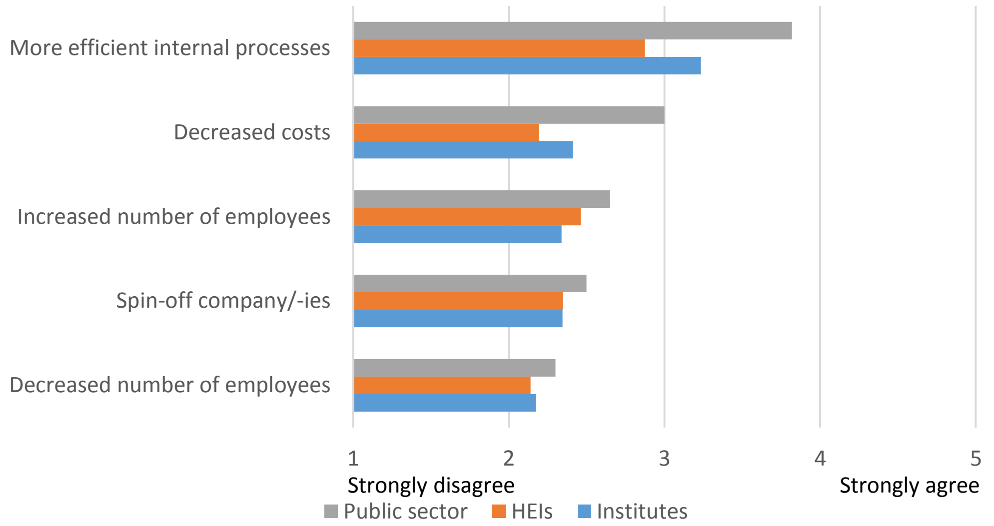

Figure 11 The extent to which collaborating with the institute in R&D projects has contributed to, or is expected to contribute to, economic impact for the organisation. Source: Web survey.

The expected time lag between collaborating with a TI institute as partner and economic benefits materialising for the company is shown in Figure 12; 2–5 years is the most common. Perhaps somewhat surprising, as partners, there are small differences between SMEs and large companies. The message is nonetheless clear: it takes several years before economic impact can be observed from participation in publically co-funded R&D projects.

Comparing answers for companies as clients and as partners, we find that the expected time to economic benefits is much shorter for both SMEs (Figure 13) and large companies (Figure 14) when they are clients, which seems natural. As clients, more than three times as large a share of SMEs respondents expect economic benefits within a year than when they are partners. For large companies, more than twice as many respondents expect economic benefits within a year when they are clients. These results in part validate the hypothesis formulated at the beginning of this chapter. The earlier observation that SMEs see notably greater impact in terms of increased international competitiveness, turnover and exports when they are clients also indicates that the hypothesis is valid; the greater commercial impact observed is surely a result of the work commissioned having been straightforward to implement in the company's commercial operations. The empirical data for large companies neither corroborates nor falsifies the hypothesis in this respect.

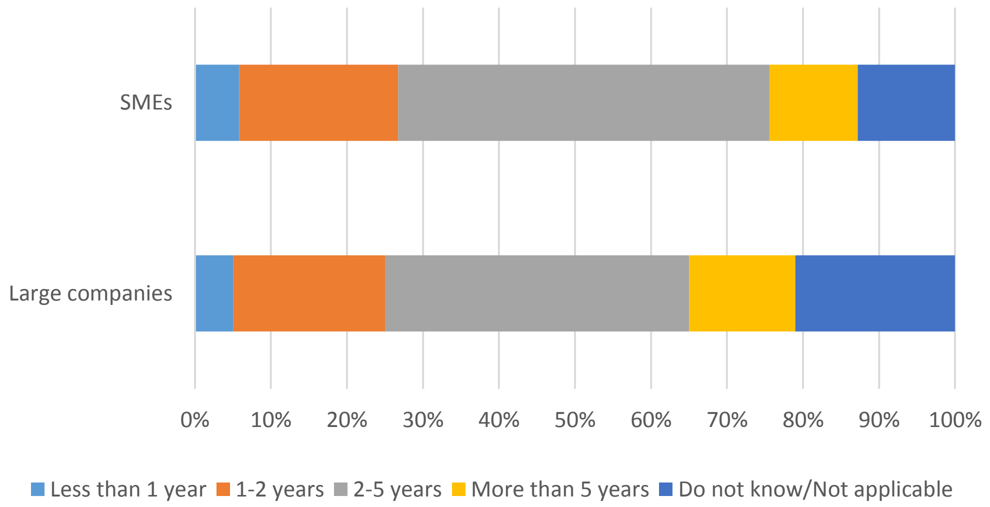

Figure 12 The expected time lag between buying R&D services from the institute and economic benefits materialising for the company. Source: Web survey.

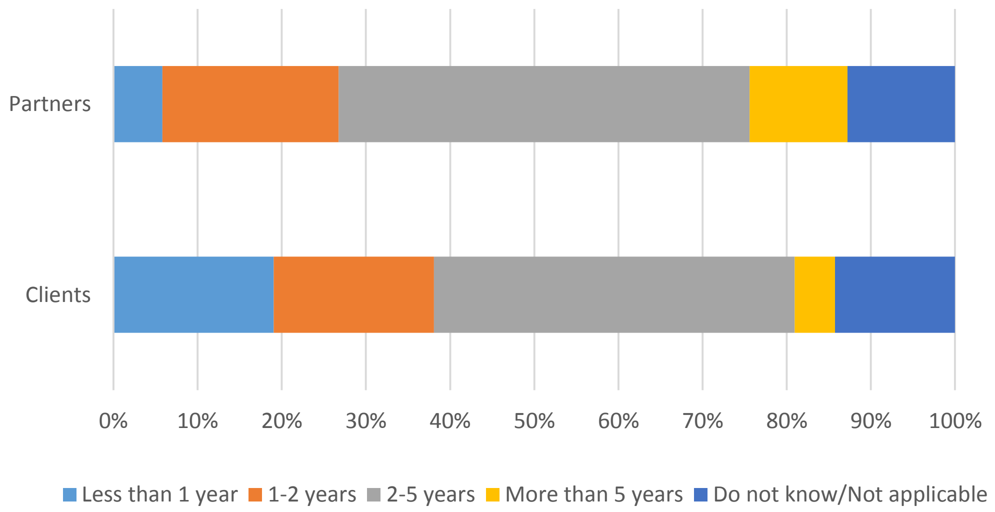

Figure 13 The expected time lag between collaborating with the institute as client and as partner and economic benefits materialising for SMEs. Source: Web survey.

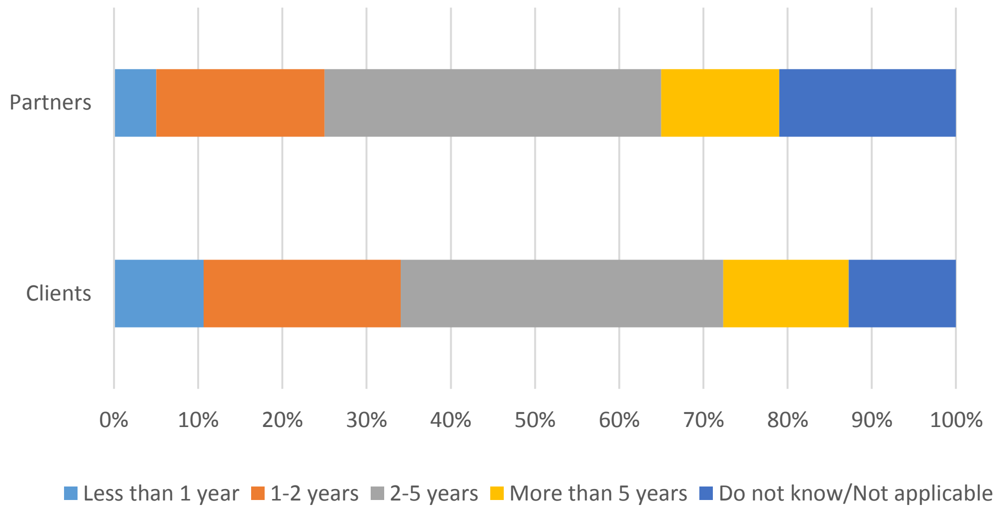

Figure 14 The expected time lag between collaborating with the institute as client and as partner and economic benefits materialising for large companies. Source: Web survey.

3. Economic impact

In this chapter, we explore the economic impact of the TI institutes through four different impact streams:

- Impact generated by the economic activity of the institutes, including:
  - **Direct economic value creation** – The value added generated by the institutes' activities.
  - **Indirect and induced economic impact** – The indirect impact measures the additional economic activity that is generated through the institutes' purchasing of goods and services from suppliers. Furthermore, there is an additional induced economic impact, which corresponds to the economic activity supported by those directly employed by the institutes and employed by their suppliers, who spend their salaries on goods and services in the wider economy. This, in turn, helps to support jobs in sectors that supply these goods and services (e.g. retail industry, banking sector etc.).
- Economic activity generated and supported by the institutes, including:
  - **Economic value created through licensing, patenting, spin-off companies** – One of the main sources of economic impact generated by the institutes comes from the exploitation and commercialisation of their research. The institutes sell licenses and patent a selection of their inventions. The overall turnover of the companies that have been spun off from the institutes provide a quantitative estimation of the impact of new companies.
  - **Wider economic impact and knowledge spillover effects** – The TI institutes' R&D activities underpin important wider economic impact, realised both through commissioned work (for clients) and through publically co-funded R&D projects (together with partners). Clients and partners alike potentially benefit from this collaboration, which may positively contribute to performance in many guises, including enhanced skills, new and improved products and processes, innovation, increased turnover, improved productivity and competitiveness. In this chapter, we explore impact on turnover and productivity from a quantitative perspective, to complement the qualitative perspective of Chapter 2.

The analyses of this Chapter do not include Uni Research, a newcomer to the TI arena, for which historical data is missing in NIFU's R&D statistics bank (and thus in RCN's annual institute reports).

3.1 Direct economic value creation

The TI institutes, just like all other sectors in Norway, generate economic activity through their operations. The base funding provided by the government through RCN on the one hand funds the institutes' basic R&D activities, but more importantly makes it possible for them to attract further income in the form of collaborative R&D projects (co-funded by RCN and other public agencies), commissioned work and assorted other activities, most of which are conducted in collaboration with other organisations. The R&D results, technologies and other knowledge generated in these activities are diffused to other organisations, both through the activities themselves and through dedicated dissemination activities, licensing and patenting.

The total operating turnover provides a first estimate of this economic activity. It also permits an estimation of the level of leverage of public funding i.e. how many additional NOK the institutes attract for each NOK invested by the Norwegian government.

However, neither the total turnover nor the total expenditure of the institutes reflect the additional value generated by their economic activity, as this total expenditure includes the purchase of intermediate goods and services used in their operations (from electricity to research infrastructure bought from other organisations). A better approximation of the value added of the TI institutes, which avoids double counting the economic activity generated by other sectors, can be obtained by looking at the value of income after discounting the cost of intermediate goods and services ("expenditure approach") or by looking at the income earned by individuals (salaries) and organisations (profits) in the production of outputs (goods or services) ("income approach"). More specifically, the value added generated by the institutes may be estimated by studying salaries and social security costs, and operating result.[11]

The remainder of this subsection analyses the different income streams of the TI institutes, their level of leverage and the value added. We also conduct an econometric exercise to test the relationship between Norwegian public funding and other sources of income to test whether an increase in public funding generates an increase in income from other sources ("crowding in") or a decrease ("crowding out").

This section utilises financial data for the TI Institutes provided by NIFU from its R&D statistics bank. Most of the information covers the period 1997–2013, and the time series have been adjusted for inflation using Statistics Norway's Consumer Price Index which uses 1998 as its base year.

3.1.1 Turnover

3.1.1.1 Turnover development

The TI institutes have together had an operating turnover of NOK44.7bn in the period 1997–2013 (real prices 1998-fixed). The annual turnover remained fairly stable between 1997 and 2006 (around NOK2.3bn), but increased thereafter, see Figure 15. Between 1997 and 2013, turnover increased from NOK2.3bn to NOK3.3bn, which represents a growth of 43 per cent.

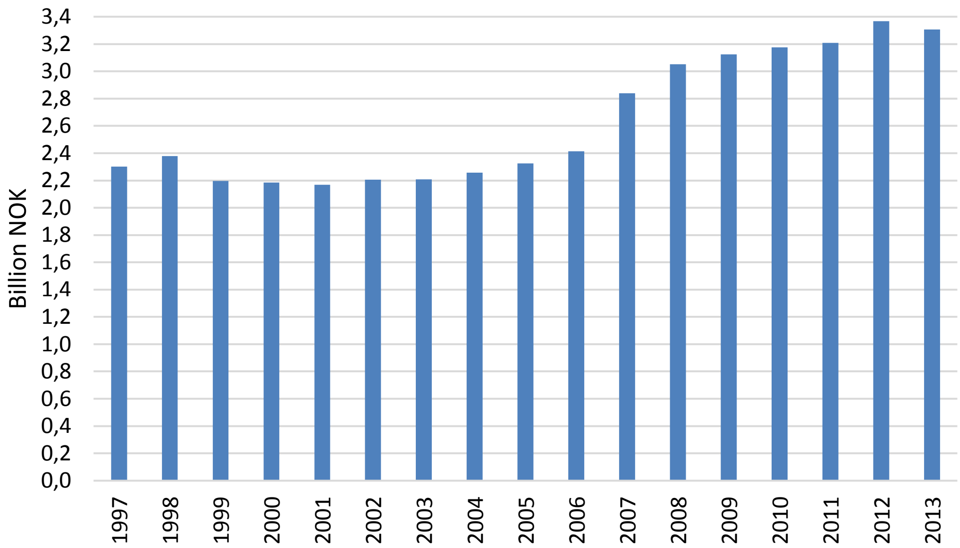

Figure 15 Total turnover of TI institutes (billion NOK, real prices 1998-fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank.

[11] L. Hobbelstad Simpson, "Norwegian Methodology for Supply and Use Tables and Input-output tables", Statistics Norway, 2009; "UK National Accounts – a short guide", Office for National Statistic, UK, 2011.

Figure 16 shows the trends in turnover per employee and per researcher, both in full-time equivalents (FTEs). Turnover per FTE employee has increased from NOK0.8m to NOK1.2m between 1997 and 2013, while turnover per FTE researcher has increased from around NOK1.4m to NOK1.8m. (We further analyse the number of employees in Section 3.1.2.1).

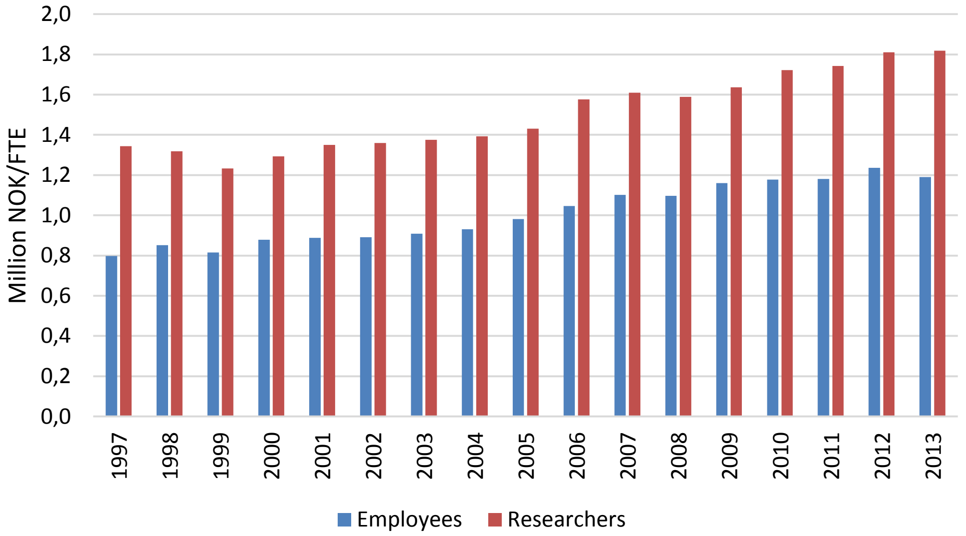

Figure 16 Total turnover income per FTE researcher and employee (million NOK, real prices 1998–fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank.

3.1.1.2 Sources of turnover

NIFU's R&D statistics bank provides a division of the TI institutes' income into the following sources:

- RCN base funding
- RCN grants
- Norwegian ministries and public administration:
  - Commissioned work
  - Management tasks and other[12]
- Norwegian industry:
  - Commissioned work[13]
  - Other[14]

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[12] Includes income from other Norwegian R&D providers in publically co-funded collaborative projects (transfers), from public agencies for commissioned work that has not been publically procured, from licenses and publications sold to public organisations, rental income from public organisations, etc.

[13] In RCN's instrument Innovation projects for the Industrial Sector (IPN), it is rather common that participating companies subcontract part of the work to TI institutes. The same applies to the R&D tax relief SkatteFUNN scheme. These subcontracting services are thus paid for with a mix of public and private money, and RCN does not have information on the ratio. According to RCN, a "significant" share of what is labelled as commissioned work for Norwegian industry is thus in effect paid for with funds that have a public origin.

- Foreign:
  - Commissioned work for industry
  - EU project funding
  - Other[15]

Figure 17 presents a breakdown of the total turnover of the TI institutes by source. Please note that the legend entries are in the same order as the areas in the figure. The Other foreign sources category includes both commissioned work for the private sector and other foreign sources of income.

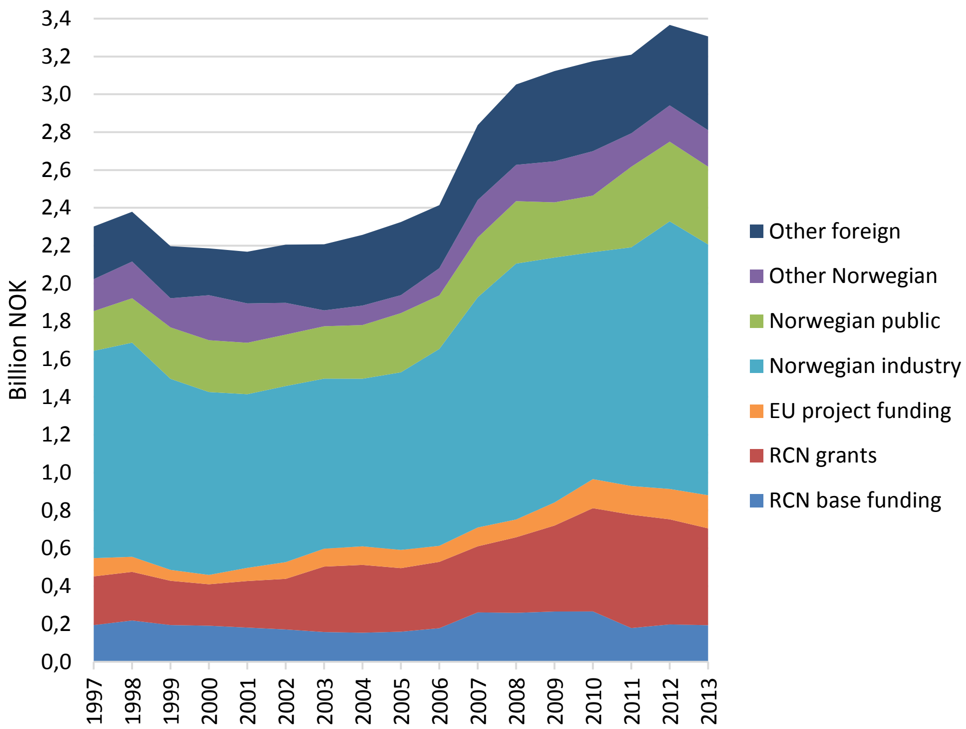

Figure 17 Sources of turnover (billion NOK, real prices 1998-fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank.

Using the data of Figure 17, Figure 18 illustrates that the share of income from Norwegian industry has decreased significantly, from 48 per cent in 1997 to 40 per cent in 2013. In the same time period, income from RCN (base funding and grants) has increased from 20 to 21 per cent, and EU project funding from 4 to 5 per cent. While the share of income from Norwegian industry has decreased considerably, the shares of income from Norwegian and European public sources have increased slowly.

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[14] Includes income from Norwegian private non-profit organisations, from licenses and publications sold to private organisations, rental income from private organisations, etc.

[15] Includes income from commissioned work for public organisations, foreign R&D providers in publically co-funded collaborative projects (transfers), income from Nordic and international organisations (mainly public), etc.

Although the increase in EU project funding may seem insignificant, it is with an increase of 26 percentage points in 16 years not, courtesy of Norway's strong participation in FP7. According to the latest FP7 Monitoring Report, Norway ranks second in terms of number of proposals and requested EU contribution among candidate and associated countries, and shows a strong participation in the thematic areas of ICT, Research for the benefit of SMEs and Environment (including climate change).[16] Furthermore, SINTEF Foundation holds the 18th position in the ranking of the top 50 Research organisations in FP7 in terms of number of participations in the 2007–2013 period. SINTEF Foundation has participated in 204 projects and has received a total EU contribution of €117m in six years (approximately NOK1bn).

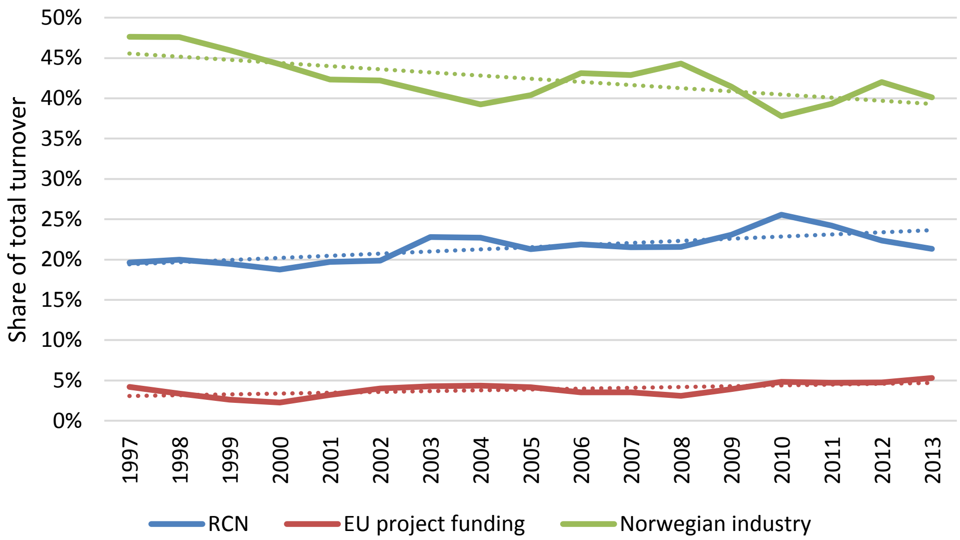

Figure 18 Shares of total turnover with linear trend lines. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

3.1.1.3 Leverage

We have explored the relative importance of Norwegian public funding and commissioned work on the TI institutes' turnover. Norwegian public funding (RCN base funding, RCN project funding, income from management tasks and funding from other public sources, but *not* commissioned work for the public sector) accounted for 25.4 per cent of turnover in 2013, while EU project funding (also public) accounted for 5.3 per cent. Figure 19 illustrates that Norwegian clients together accounted for 54.3 per cent of turnover, and foreign clients for 15.0 per cent.

16 "Seventh FP7 Monitoring Report. Monitoring Report 2013", European Commission.

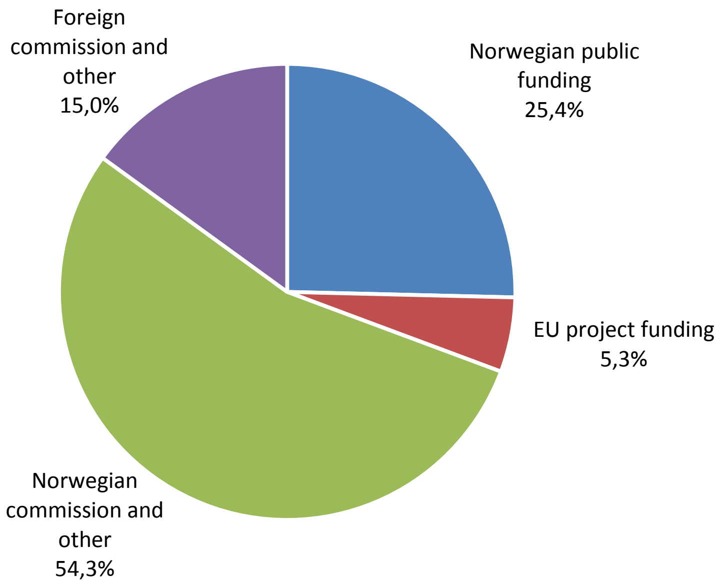

Figure 19 Norwegian versus foreign sources of funding in 2013. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

Figure 20 shows that commissioned work for the private sector (Norwegian and foreign combined) accounted for half of turnover in 2013, and commissioned work for the Norwegian public sector for 8.4 per cent, a total of 58.3 per cent.

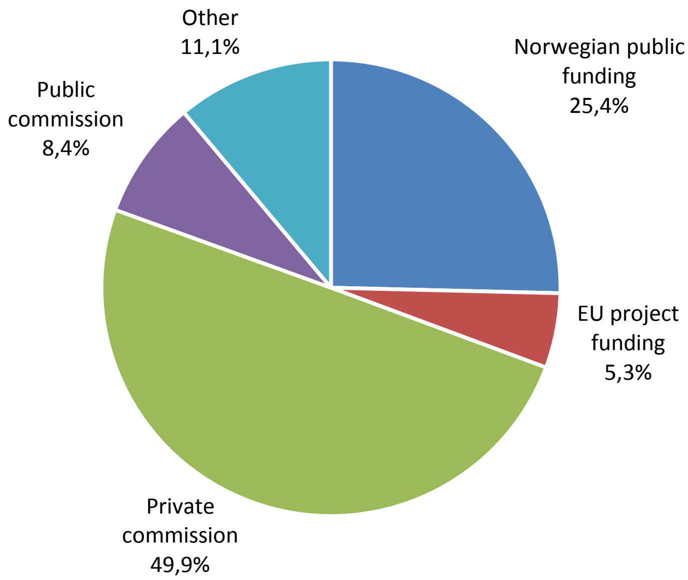

Figure 20 Public versus private sources of funding in 2013. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

We further examined the extent to which the TI institutes have managed to attract additional funding, thus leveraging the investment of the Norwegian public funding. For the purposes of this exercise, we have classified their entire income into two categories:

- Norwegian public funding: Just as in the previous two figures, this includes RCN base funding, RCN project funding, income for management tasks and funding from other public sources. Norwegian public funding amounted to NOK10.2bn in the period 1997–2013 (real prices 1998-fixed)

- Other income: Commission income (Norwegian public, Norwegian private and foreign), EU project funding and other foreign sources. Other income amounted to NOK34.5bn in the period 1997–2013 (real prices 1998-fixed)

The ratio of Other income to Norwegian public funding for the entire period 1997–2013 has been 3.4. This means that for each NOK of Norwegian public funding, the TI institutes have managed to attract an additional NOK3.4 from other sources, which illustrates the multiplying effect of the Norwegian public investment. However, Figure 21 shows that this ratio has dropped significantly, from 4.0 in 1997 to 2.9 in 2013. The main reasons for this development is the decreasing share of income from Norwegian industry and the simultaneously increasing shares of income from RCN and EU project funding (cf. Figure 18). However, it is important to bear in mind that an unknown but "significant" share of what is labelled as commissioned work for Norwegian industry is paid for with funds that have a public origin (cf. footnote 13). Had we been able to account for this, the ratio would have been notably lower, and the decline likely steeper (considering the overall decline in share of income from Norwegian industry, cf. Figure 18).

To further understand the interaction between these two categories of income, we have conducted a statistical and econometric analysis to test how TI institutes would respond in the future to a hypothetical change in public funding. The main question here is whether or not Norwegian public funding crowds in income, i.e. that an increase in funding leads to an increase in income from other sources (crowding in), or whether it has the opposite effect (crowding out).

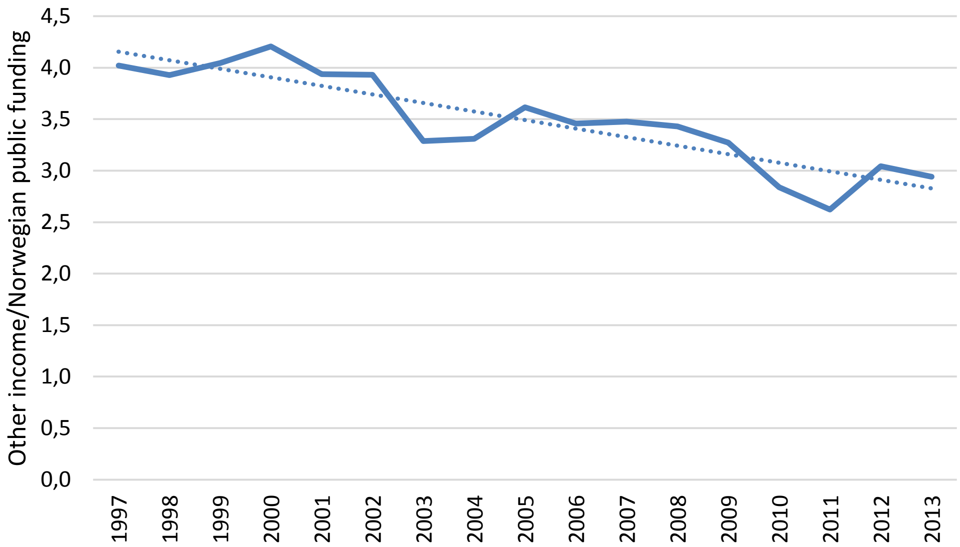

Figure 21 Institutes' ability to leverage Norwegian public funding. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

Figure 22 shows the change (in million NOK) of Norwegian public funding from one year to the other (*t*+1 vs. *t*) on the x-axis, and change in (future) Other income in subsequent years on the y-axis. The orange dots represent the change Other income in year *t*+1 (*t*+1 vs. *t*) and the blue dots Other income in year *t*+2 (*t*+2 vs. *t*). Each orange dot represents a pair of values (change Norwegian public funding in year t and change in Other income in year *t*+1), one for each institute and each year. The same goes for the blue dots. The figure shows a weak positive relationship between change Norwegian public funding and (future) change in Other income. In fact, the correlation factor equals 0.22. The figure shows that in most cases, an increase in

Norwegian public funding (in year *t*) is matched by an increase in Other income in years *t*+1 and *t*+2. Thus, for example, an increase in Norwegian public funding in 2001 is positively correlated to an increase in Other income in 2002 and 2003.

We have conducted an econometric analysis to test whether a change in Norwegian public funding in a given year indeed triggers a change in the level of Other income in subsequent years, even after controlling for some additional factors, and to quantify that change. We used a linear regression model (Ordinary Least Squares, OLS) and conducted two exercises:[17]

1. In Model 1, we used the (logarithm of) Other income in year *t*+1 as dependent variable
2. In Model 2, we used the (logarithm of) Other income in year *t*+2 as dependent variable

The main explanatory variable is (the logarithm of) Norwegian public funding (in year *t*). We also included a variable for the number of FTE employees (to control for the size of the institute) and a dummy variable for each institute, to control for institutes' fixed effects. (Our model draws 14 linear regressions that best fit the data, one for each institute, instead of a single linear regression. The final coefficient of change is presented as the average of the 14 individual coefficients calculated.)

[17] We use log transformations of income as the data is highly skewed (with many institutes concentrated around the lower bound in terms of income). Once the log transformation is applied the data shows a normal distribution, which is a desirable condition for the type of linear regression we use in this exercise.

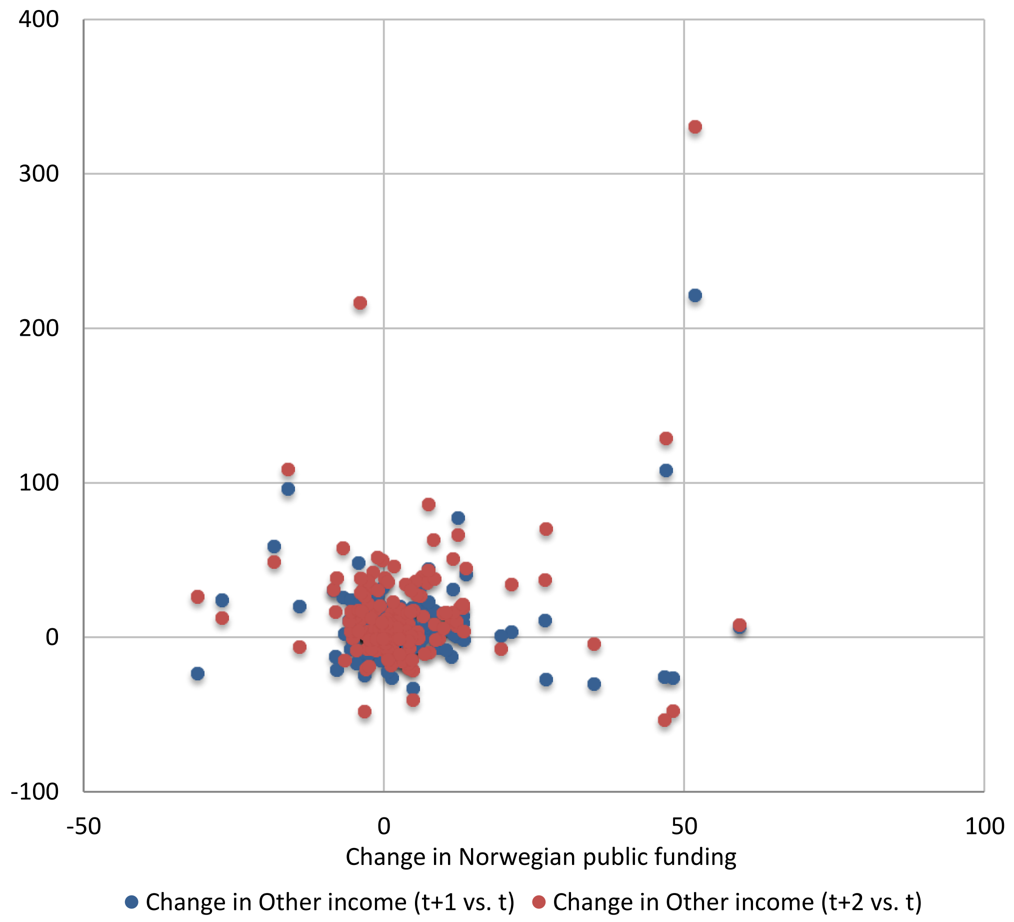

Figure 22 Relationship between income from Norwegian public sources and Other income (million NOK, real prices 1998-fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank.

The regression provides coefficients that capture the relationship between dependent and independent variables, which are the numbers presented in Table 6. If the coefficients are positive and have a p-value lower than 0.05, then we can say that the relationship between two variables is positive and statistically significant. The first row of the table indeed shows that the relationship between the dependent variable and the main explanatory variable is positive and statistically significant (at 99 per cent confidence level). Furthermore, the R-squared value is very high, 0.95, which means that the explanatory variables added to the model explain 95 per cent of the variance in the dependent variable. This implies that resources are complementary and that an increase in Norwegian public funding results in an increase in Other funding (1 or 2 years later) rather than leading to a decrease or a replacement.

Table 6 Estimations of leverage using an econometric approach (OLS). Standard errors are shown in parenthesis below the coefficients. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

	Model 1 (year *t*+1)	**Model 2 (year *t*+2)**
(Log) income from Norwegian public funding (year *t*)	0.295*** (0.046)	0.305*** (0.046)
Total FTE[18]	-0.001 (0.001)	0.000 (0.001)
Institutes' fixed effects	Yes	Yes
R-squared	0.967	0.967
Number of observations	208	195

* p-value<0.05, ** p<0.01, *** p<0.001

The coefficient of the main explanatory variable in Model 1 means that a 10 per cent decrease in Norwegian public funding in year *t* results in a 2.9 per cent decrease in funding from other sources in year *t*+1 (where 2.9%=(1.10^0.295-1) x 100). The coefficient in Model 2 is slightly higher, but also positive and statistically significant. The results in Model 1 implies that the effect leverage kicks in almost immediately, while the results in Model 2 show that the effect is even stronger in the subsequent year.

See Appendix A.1 for a mathematical representation of the exercise and the transformation of the coefficients obtained. These results support the importance of Norwegian public funding as an enabler of the TI institutes' activities and its multiplying effect for the TI institutes' ability to secure further income, as well as the expected negative effect of a potential decrease in funding.

3.1.2 Value added

As explained at the beginning of Section 3.1, the direct economic impact of the TI institutes is equivalent to the institutes' value added, which in turn can be measured as the sum of personnel costs (salaries and social security costs) and the institutes' operating result.

3.1.2.1 Employment

Figure 23 shows the development of FTE employees of the TI institutes. At present, the institutes employ approximately 2,700 FTEs, of which around 1,800 are researchers, thus representing two thirds of the total workforce.

The total personnel costs of the TI institutes amounted to NOK25.8bn between 1997 and 2013. The personnel costs, including salaries and social security costs, represent 57.5 per cent of the total costs (NOK45bn) in the period. Figure 24 shows the development of personnel costs over time. Given that the number of employees has remained fairly stable, salaries (and possibly social security costs) appear to have been growing steadily over the years, even after accounting for inflation.

[18] The FTE variable probably is not significant because the Institutes' fixed effects already account for variances in the results that are explained by the differences in size of the institutes.

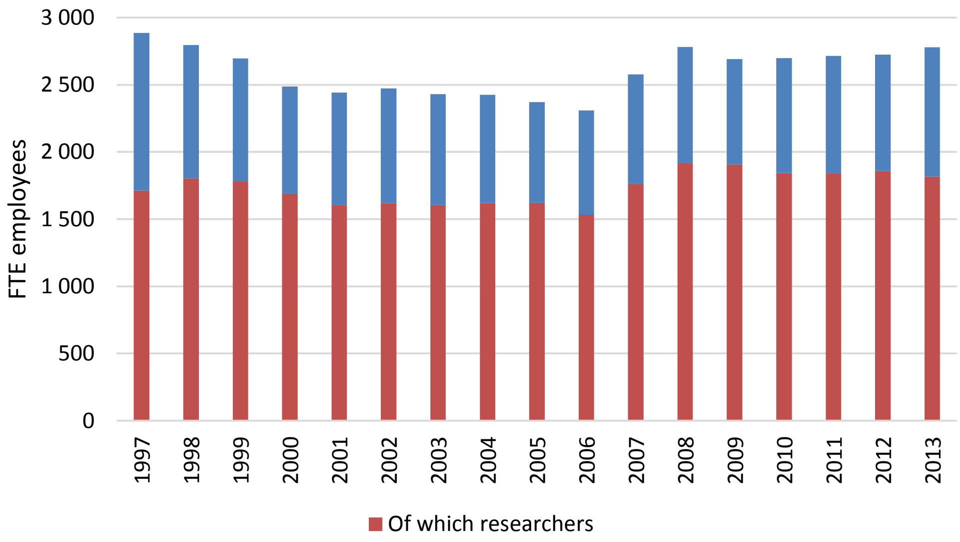

Figure 23 Total FTEs of TI institutes. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

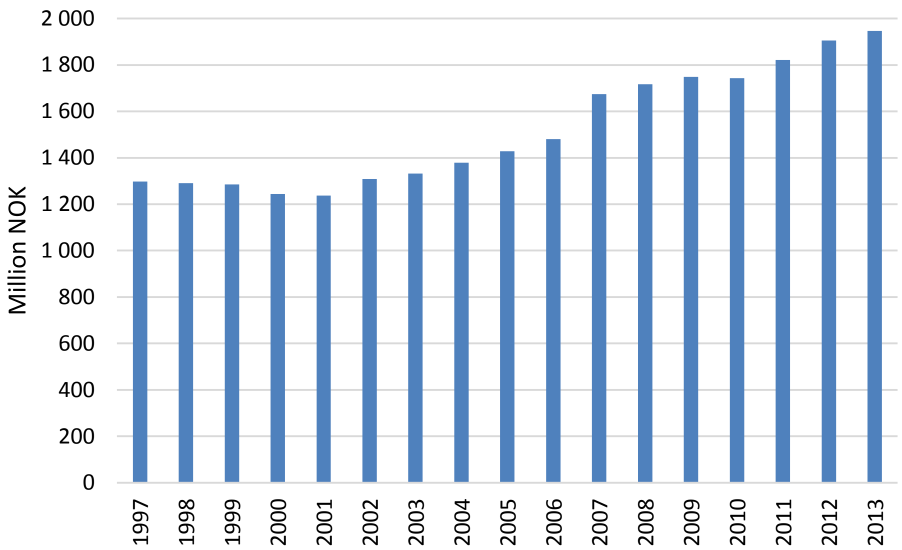

Figure 24 Personnel costs of TI institutes (million NOK, real prices 1998-fixed). Technopolis analysis of data from NIFU's R&D statistics bank.

In the 2001–2013 period, the TI institutes' personnel obtained 416 doctoral degrees. This includes 156 doctoral degrees where at least 50 per cent of the doctoral work (minimum 18 months) was performed at an institute, or where an institute shouldered at least 50 per cent of the costs. Figure 25 shows the evolution of doctoral degrees over time and a comparison with the overall trend in doctoral degrees awarded in Norway. (The share of doctoral degrees supported by an institute was not reported prior to 2006.) The total number of degrees awarded to TI institute personnel represents 3.1 per cent of the total number of doctoral degrees awarded in Norway in the same time period.

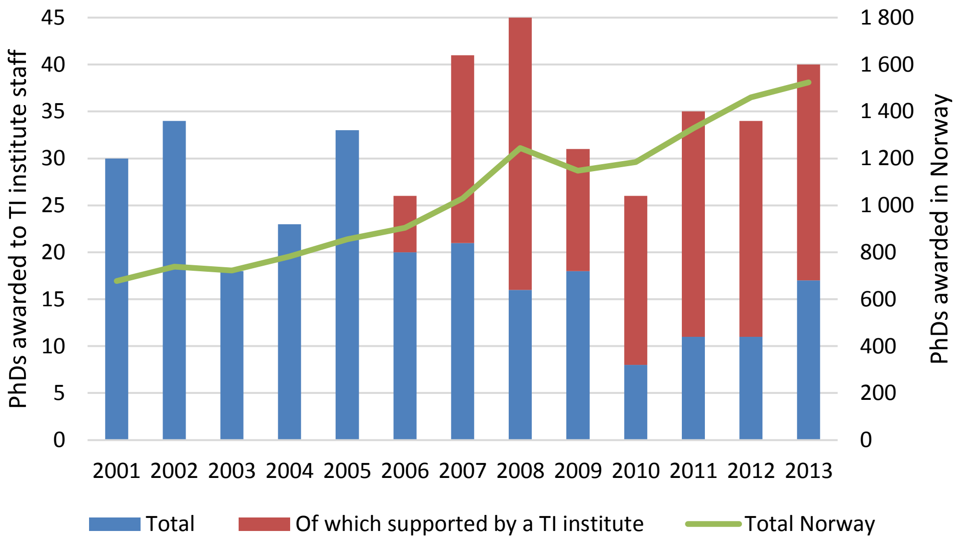

Figure 25 Number of PhD degrees co-produced by the TI institutes on left axis. Data for Norway on right axis. Technopolis analysis of data from NIFU's R&D statistics bank and Eurostat.

3.1.2.2 Profit

The TI institutes' compound result before tax has in most years been positive, see Figure 26. The compound profit before tax was NOK1.1bn in the period 1997–2013 (real prices 1998-fixed). Almost one third of this profit has been paid to the government in the form of taxes (NOK384m).

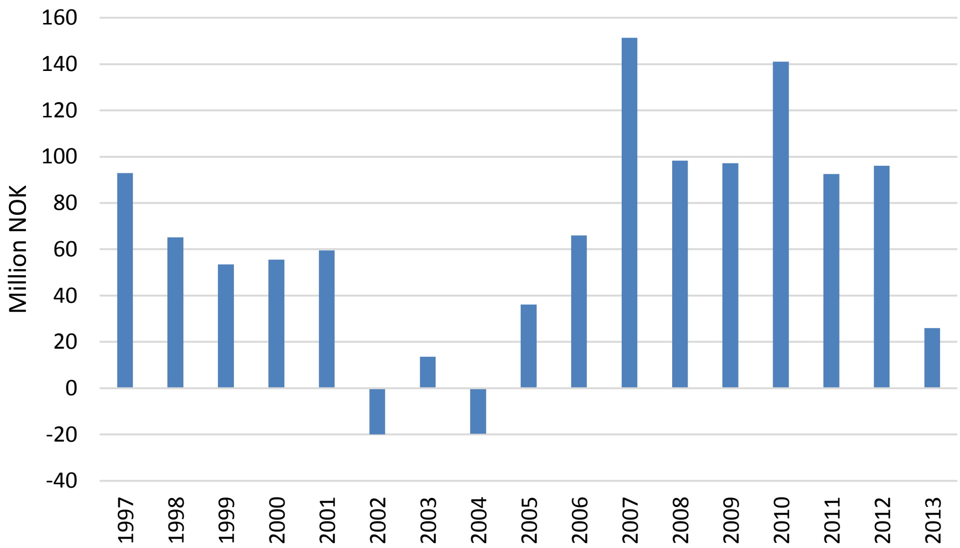

Figure 26 Result before tax for TI institutes (million NOK, real prices 1998-fixed). Technopolis analysis of data from NIFU's R&D statistics bank.

The institutes' profit margin (result over turnover) has been above 2 per cent in most years, see Figure 27, which may be considered quite a good performance since the institutes are not expected to produce any profit for their owners, only to make a small profit to reinvest in their own operations, as well as to have a certain preparedness for possible future bad years.

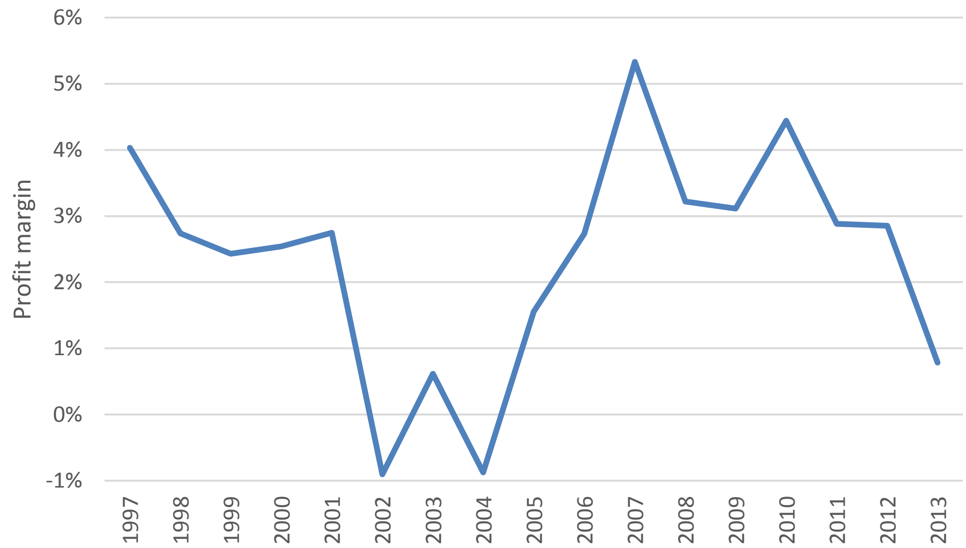

Figure 27 Profit margin (profit over turnover) for TI institutes (million NOK, real prices 1998-fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank.

3.1.3 Summary

Table 7 summarises that, with the NOK10.2bn in Norwegian public funding in the period 1997–2013, the TI institutes managed to attract an additional NOK34.5bn in income from other sources, translating into an overall ratio of 3.4.

The direct economic impact (value added) of the TI institutes was NOK26.9bn in the same period. This means that the return on Norwegian public investment – if we only take into account the direct economic impact – was 2.6.

Table 7 Overview of funding and value added 1997–2013 (million NOK, real prices 1998-fixed).

	Total
Leverage	
Norwegian public funding [A]	NOK10.2bn
Other income [B]	NOK34.5bn
Ratio [B]/[A]	**3.4**
Direct economic impact	
Norwegian public funding [A]	NOK10.2bn
Value added:	
Personnel costs (salaries and social security)	NOK25.8bn
Profit before tax	NOK1.1bn
Total value added [C]:	**NOK26.9bn**
Ratio [C]/[A]	2.6

3.2 Indirect and induced economic impact

In addition to the institutes' direct impact, as measured by the value added they generate, there is additional economic activity generated by the expenditure made by their employees, including:

- Indirect impact, which is the additional economic activity that is generated through the institutes' purchasing of goods and services from suppliers
- Induced impact, which is the economic activity supported by those directly employed by the institutes and employed by their suppliers, who spend their salaries on goods and services in the wider economy

The final indirect and induced economic impact may be calculated using an output multiplier, which is calculated as follows:

$$Output\ multiplier = \frac{(Direct + Indirect + Induced\ impact)}{Direct\ impact}$$

Multipliers are estimated using input-output (IO) tables. An IO table of a given industry is a matrix that maps all the sectors that participate in the supply chain of the industry (or segment of industry) in question and quantifies the purchases of goods and services that they trade with each other. It also estimates the number of employees that are part of the full supply chain. See Appendix A.2 for an explanation of how multipliers are obtained from IO tables.

The study team commissioned Statistics Norway (SSB) to calculate a bespoke multiplier in order to obtain as accurate an estimate as possible for the "institute sector", which is a terminology used by SSB to refer to all R&D institutes that are not part of a university (i.e. not only the TI institutes). Using its in-house model and based on an IO approach, SSB estimated the effect that an increase in output of the institute sector (through an increase in R&D expenditure) has on other sectors of the Norwegian economy (see Appendix B for details). SSB estimates that the IO multiplier for R&D investment produced by the institute sector on gross production is 1.368 (in 2012). (This value agrees rather well with the only appropriate secondary source of output multiplier that we found, which estimated an output multiplier of 1.52 for "scientific research and development services" in Norway.[19])

With SSB's output multiplier and the direct economic impact (total value added from Table 7), we may use the equation above to estimate the sum of the indirect and induced impact for the period 1997–2013 to NOK9.9bn. This is the value of the additional economic activity generated by the direct economic impact of the TI institutes.

3.3 Economic impact generated by the institutes' activities

The economic impact generated by TI institutes' activities is the sum of direct economic impact (NOK26.9m) and indirect and induced impact (NOK9.9bn), i.e. **NOK36.8bn** in the period 1997–2013 (real prices 1998-fixed).[20]

3.4 Economic value created through licensing, patenting, spin-off companies

One of the main sources of economic impact generated by the institutes comes from the exploitation and commercialisation of their research. In this section we present an overview of the patenting and licensing activity of the institutes to then focus on the economic value generated by the companies that have spun out from the institutes since 1997.

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[19] "Economic Growth Potential in the Norwegian and Swedish Equine Sectors in a National and Regional Perspectives", NILF, 2012. Project partially funded by RCN in collaboration with the Swedish University of Agricultural Sciences.

[20] It should be noted that that economic impact as described here (i.e. the sum of direct, indirect and induced impact) applies to *any* economic activity and is an approach commonly used to analyse the impact of public expenditure, irrespective of sector.

3.4.1 Patents

The TI institutes are highly active patenting their inventions. According to NIFU's R&D statistics bank, they have filed a total of 1,008 patents applications (in Norway and abroad) in the period 1997–2013. We used the EPO Worldwide Patent Statistical Database (PATSTAT) to look for additional information on technology areas covered by these patents, as well as indications of quality and knowledge dissemination.[21] Using the name of the TI institutes and their unique identifiers, we found 388 patent applications in PATSAT, i.e. a mere 38 per cent of the total reported by the TI institutes to NIFU. We have not found a definite explanation for this discrepancy. One possible explanation is the way that PATSTAT registers EPO patent applications (patent applications that are registered in the European Patent Office and that can offer protection in all Contracting States). These patent applications only appear once in PATSTAT and not several times (one per each Contracting State in which the applicant has applied for protection), as may be the case with the data reported by the TI institutes.[22]

Figure 28 shows the distribution of the institutes' patent applications across five main technology areas, using PATSTAT data and calculated via fractional counting.[23] Obviously, the majority of applications (37%) belong to the Instruments area, which includes optics; analysis, measurement, and control technology; medical technology and nuclear engineering, followed by Chemistry (29%), Electrical engineering (15%) and Mechanical engineering with (11%).

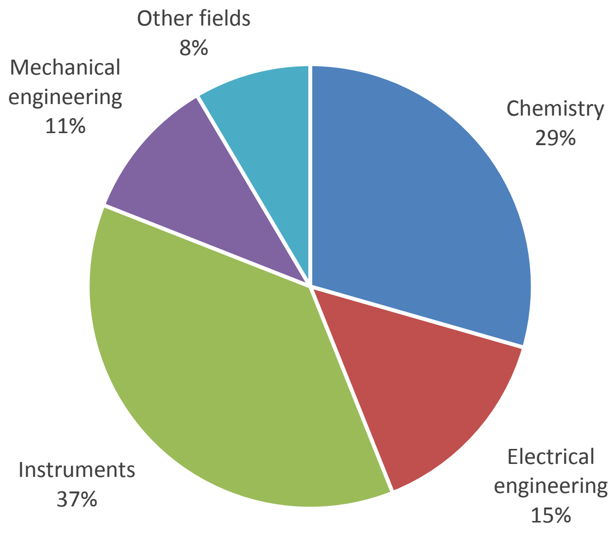

Figure 28 Patent applications from institutes by technology area 1997–2013. Source: Technopolis analysis of data from PATSTAT (autumn 2014). Based on 388 applications.

[21] PATSTAT is the most comprehensive patent database in the world. It contains over 70 million records of patent applications (as well as utility models and design rights) filed in 170 IP offices around the word as far back as 1844. It comprises detailed information on those applications including application year, characteristics of applicants and inventors (geography, type of organisation), application authority, technological area, status (granted, pending), among other indicators.

[22] An applicant may designate one or more Contracting States when filing a European patent application. There are 38 Contracting States, which include the 28 EU Member States.

[23] Each patent application is usually classified into more than one technology area and fractional counting has been used to avoid double counting.

The number of times a patent is cited is generally accepted as an indicator of a patent's "quality", or at least the extent to which knowledge of the patented technology has been disseminated and is subsequently referenced as "prior art". Although there is evidence that the most valuable inventions are never patented, for publically co-funded institutes this measure of a patent's quality is useful as it gives an idea of the scale of further work that builds upon inventions produced by the institutes. The number of citations can therefore be seen as a proxy for the amount of knowledge that is disseminated from the TI institutes. Using the detailed citation information available in PATSTAT, we calculated the average number of citations for patent applications submitted by TI institutes between 1997 and 2013. We also calculated the average citations for all patent applications for Norwegian applicants in the same time period and technology area to ensure comparability.

We have chosen 1998 as an example to compare the citations to patent applications filed by the TI institutes and patent applications filed by all other Norwegian applicants (all over the world). We choose this year given that a citation analysis for patent applications is more relevant when looking at older applications (newer applications tend to be cited less), but also because this was a year with a high number of applications across all the institutes which provided the opportunity to find larger number of records in PATSTAT. The results of this exercise are presented in Figure 29, and it is clear that the number of citations per patent application in Electrical engineering and Instruments is significantly higher than the average in these fields for all Norwegian applicants.

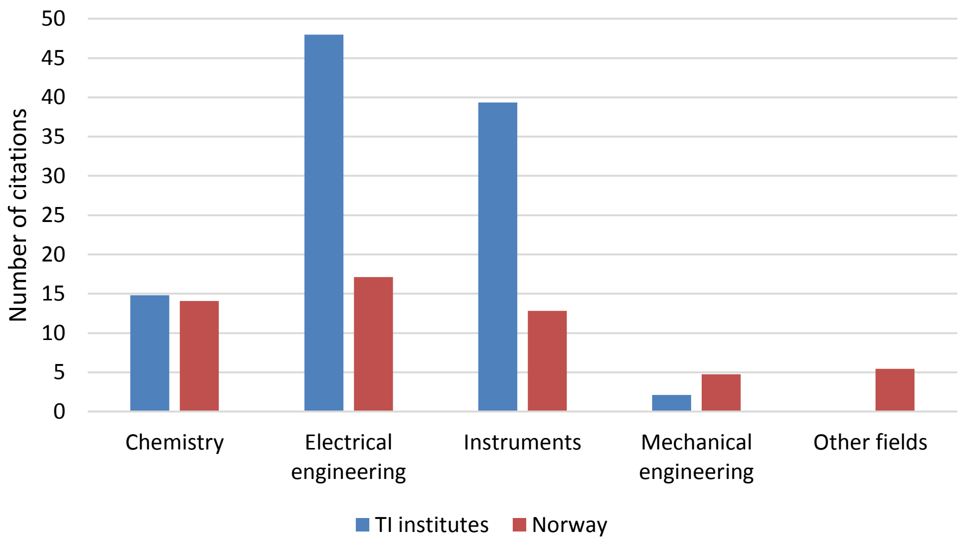

Figure 29 Mean number of citations per patent application by technology area for the TI institutes and all Norwegian patent applications in 1998. Source: Technopolis analysis of data from PATSTAT (autumn 2014). Based on 388 applications.

This means that the knowledge created by the TI institutes (and codified in the form of patent applications) is of higher quality and impact (in terms of knowledge dissemination) than the knowledge patented by other Norwegian organisations. This knowledge is proving useful to, and is being built upon by, others. Some of this new knowledge has most certainly translated into increased competiveness and efficiency gains for Norwegian (and foreign) companies.

3.4.2 Licensing

According to NIFU's R&D statistics bank, the TI institutes have had a licensing income of NOK207m in the years 1997–2013 (real prices 1998-fixed), but the income varies significantly from year to year. Licensing income obviously only represents a small fraction of the institutes' total income.

3.4.3 Spin-off companies

According to NIFU's R&D statistics bank, 117 companies have been spun off from the TI institutes since 1997, see Figure 30. The number of companies founded per year seems to be on a declining trend, but a significant number of companies were founded in certain individual years: 20 in 2000; 15 in 1997; 12 in 2009 and ten in 1999 and 2001.

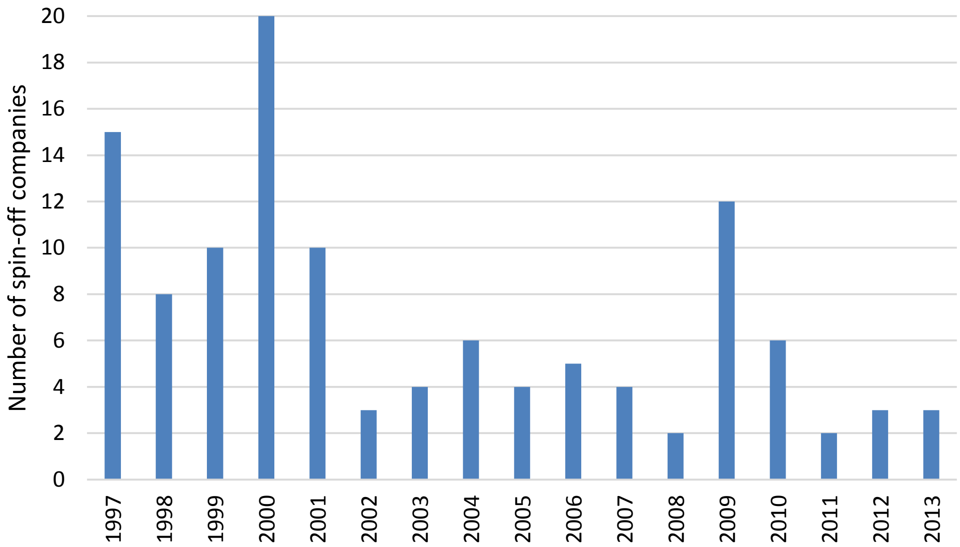

Figure 30 Number of companies spun off from the TI institutes. Source: Technopolis analysis of data from NIFU's R&D statistics bank.

The institutes report the names of the companies that they have spun off. In order to get a better sense of the economic activity generated by these new companies, we matched each company name to the Eniro database of Norwegian companies' economic data. Since the institutes only report the companies' names (and not organisation number), it is a challenge to match these with the Eniro database. Using the STATA data management software and its built-in regular expressions and additional manual cross-referencing, we matched 81 of the 117 companies in Eniro (70%), a suitable sample of the population.

We then tested whether there are any systematic differences between the 81 companies found in Eniro and those not found. We compared companies based on year of foundation and headcount at the year of foundation (the only two spin-off company indicators available in NIFU's R&D statistics bank), and we found no major difference between the two sets of companies in terms of year of foundation, which means that we are not missing only the newest or even the oldest companies. (Since it can take up to around two years before a new company has to file its first accounts, it would have been natural to find that the newest companies were not found in Eniro, but the missing companies have not only been founded in the last two years.) We also did not find any major difference in the headcount at the year of foundation. This implies that companies not found are not systematically different from the ones found in Eniro. It could also be that some companies did not survive more than two years and for that reason were not found in Eniro. However, we do not have data to test this hypothesis, but we do take into account survival rates when grossing up sales to include missing companies.

The left part of Table 8 shows the most common industry sectors of the spin-off companies, as reported in NIFU's R&D statistics bank. It shows that many spin-off companies are active in the IT, Construction and Consultancy industries. The Eniro database provides a different sector classification, with a closer description of the companies' activities rather than the industry in which they operate. Technical consultancy and R&D services are the most common.

Table 8 Industry sectors of spin-off companies. Source: Technopolis analysis of data from NIFU's R&D statistics bank and Eniro's company database.

All spin-off companies (117)		**Spin-off companies found in Eniro (81)**	
Industry	**Count**	**Type of activities**	**Count**
IT	11	Other technical consultancy	17
Construction	9	Research and experimental development	7
Consultancy	7	Other consultancy services	5
Petroleum	6	Development of software	3
Energy	5	Portfolio investments	2
R&D	4	Design activities	2
Oil and Gas	4	Other business activities	2
Biotechnology	3	Other	43
Drilling/Well Technology	3		
Environmental Engineering	3		
Other	62		

Examples of spin-off companies include:

- Electromagnetic Geoservices ASA, which uses proprietary marine electromagnetic technology to support oil and gas companies in their search for offshore hydrocarbons. The company was spun off from NGI in 2002. In 2013, it had a turnover of NOK1bn and 175 employees. This company strongly dominates the aggregated turnover data presented below (and to a lesser extent the employee data)
- Synthetica AS was spun off from the SINTEF Foundation in 2000. Synthetica offers a wide range of services within organic chemistry, including custom organic synthesis, medicinal chemistry, analytical services and cGMP synthesis. In 2013, it had a turnover of NOK13.9m and 8 employees
- Small Turbine Partner AS was founded in 2000. A spin-off from SINTEF Energy, the company engineers, manufactures and sells patented hydropower turbines. The turbines are optimised for each project and are produced in Norway. In 2013, the company had a turnover of NOK19.6m and 5 employees

The compound annual turnover of the 81 spin-off companies found in the Eniro database are presented in Figure 31 as blue bars. This set of 81 companies had a compound turnover of NOK9.2bn in the 1998–2013 period (real prices 1998-fixed), but it should be noted that this figure is very much dominated by one company, namely Electromagnetic Geoservices described above. This is nevertheless a lower-bound figure, since it does not account for the 36 companies not found in the Eniro database. To make an estimation of the value of those companies, we conducted a thorough process to input missing values.

Since companies are founded and liquidated every year, the imputation cannot only consider the average turnover per spin-off company and assume that the missing 36 companies had a similar average turnover year by year; they were founded in different years and they survived a different period of time. Our rigorous approach had three steps:

- We estimated the probability of survival based on the information available for the 81 firms using the Cox model.[24] An additional transformation of the coefficients obtained from this model permits estimation of the probability of surviving in year *t*+1 if a company was founded in year *t*, the probability of survival in year *t*+2 if a company was founded in year *t* and so on. The full matrix of conditional probabilities can be found in Appendix A.3. The table provided in the appendix shows that if a company was founded in 1998, it had 94 per cent chance of being in operation in 1999, but only a 46 per cent chance of being in operation in 2013.
- We estimated the average turnover per year (based on the 80 companies found in the Eniro database, but after excluding Electromagnetic Geoservices). In 2013, the average turnover for this set of companies was NOK6.2m.
- We then estimated an "expected" turnover using a Bernoulli distribution for the missing companies, i.e. a linear combination of probabilities and average turnovers. So for instance, if a company was founded in 1998, we estimated that its "expected" turnover in 2013 was NOK2.9m, i.e. NOK6.2m with a probability of 46 per cent and zero with a probability of 54 per cent (=46%x6.2+54%x0).[25]

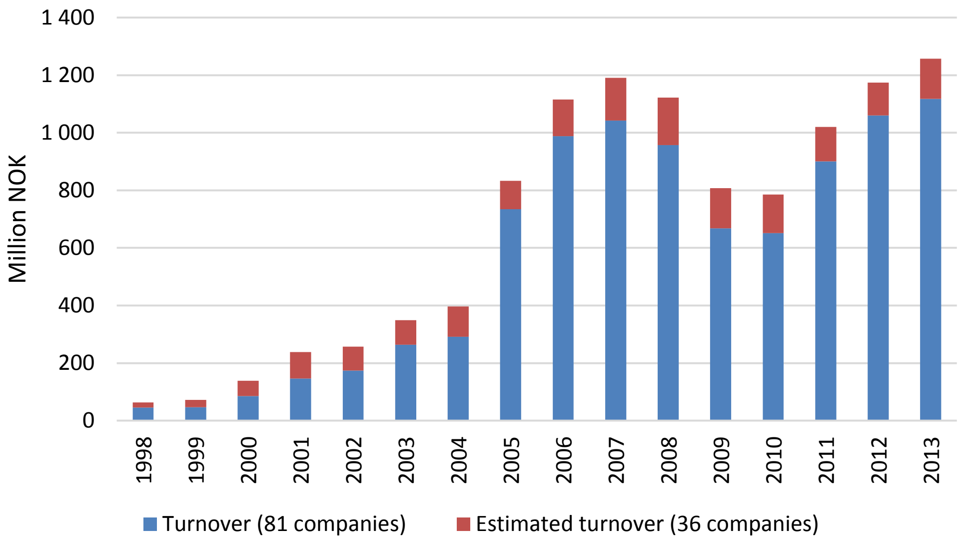

Figure 31 Turnover of spin-off companies (million NOK, real prices 1998-fixed). Source: Technopolis analysis of data from NIFU's R&D statistics bank and Eniro's company database.

Following this methodology, we estimated that an additional NOK1.6bn has been generated by the missing spin-off companies. This means that the 117 companies that have been spun off from the TI institutes have had a total turnover of NOK10.8bn in the years 1998–2013 (real prices 1998-fixed), and NOK0.7bn on average every year (once again very much dominated by Electromagnetic Geoservices). Figure 31 shows the trend for the full set of companies, where the brown parts of the bars represent the companies missing in the Eniro database. The decrease in turnover in 2009 and 2010

[24] The Cox model is a proportional hazard model, which measures the conditional probability of firm *i* dying in year *t*, given that firm *i* survived in year *t*-1, over the total probability of death in the population at year *t*.

[25] Expected value (E[x]) is equal to E[x]=x1*p1 + x2*p2 + ... + xN*pN, where p1 is the probability of outcome x1. In this case the probability of outcome "turnover in 2013 equal NOK19.3m" is 46% and the probability of outcome "turnover in 2013 equals zero" is 54%.

may of course in part be due to the decrease in spin-offs between 2004 and 2008, but it is more than anything a result of the misfortunes of Electromagnetic Geoservices, which experienced a dramatic drop in the turnover in 2009 and 2010, followed by a rapid recovery.

Figure 32 shows the number of employees of the 81 spin-off companies found in the Eniro database (the only ones we have information on). The constant growth in employment largely corresponds to the increasing number of companies, but it also supports the evidence of the turnover data that many of the companies thrive rather than falter. Since 2009, these companies have had just above 600 employees (of which 175 in Electromagnetic Geoservices in 2013).

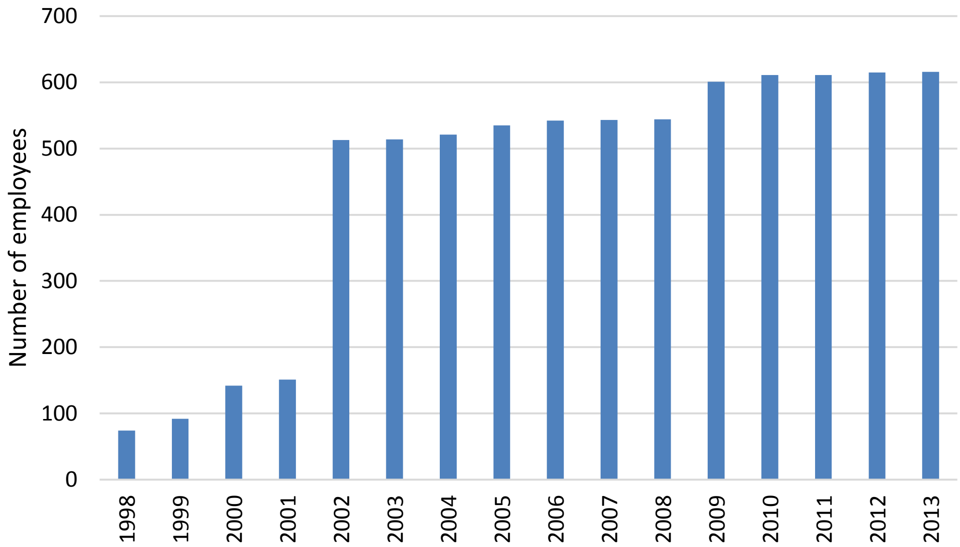

Figure 32 Number of employees of spin-off companies. Source: Technopolis analysis of data from NIFU's R&D statistics bank and Eniro's company database.

Table 9 provides a summary of the findings for companies spun off from the TI institutes.

Table 9 Summary of spin-off companies.

	Number of companies	Turnover (NOK billion)	Employment per year (average)
Companies found in Eniro database	81	9.2	452
Companies estimated	36	1.6	–
Total	**117**	**10.8**	–

3.5 Wider economic impact and knowledge spillover effects

The TI institutes' R&D activities underpin important wider economic impact through both commissioned work and R&D projects. As outlined in Chapter 2, the impact of collaborating with TI institutes, as experienced by survey respondents and interviewees, appears to be quite positive, albeit difficult to quantify based on survey and interview data alone. In this chapter, we employ econometric techniques in an attempt to quantify the impact on users.

3.5.1 Counterfactual analysis

The econometric exercise presented herein adheres to the minimum requirements for robust econometric impact analyses proposed in several guidelines.[26] To fully understand the impact and difference made by the services provided by the TI institutes, we need to estimate what would have happened in their absence. This is the so-called fundamental problem of causal inference. It is impossible to observe the real "treatment" effect (the actual development over time of the same company, with and without treatment) without making "untestable" assumptions.[27] We thus need to complement analyses of users' changing performance over time with an analysis of the performance of non-users, i.e. similar companies that have not collaborated with a TI institute. We call the first group the user group and the second the non-user group. Such a comparison is the essence of a counterfactual analysis and allows attribution between cause and effect, i.e. between collaboration with a TI institute and impact on the collaborating company. This approach obviously relies on the ability to construct an adequate group of non-users; in this case Norway-based companies that engage in R&D, but not in collaboration with a TI institute.

For the comparison to be valid, we need to address issues relating to selection bias, which can be particularly problematic in the innovation policy arena. We need to avoid the possibility that the companies of our user group share a common characteristic that is closely linked with our hypothesised outcome. For example, it is conceivable that innovative and dynamic companies on average are more likely to collaborate with the TI institutes than companies that are not innovative. Thus, if we were to compare the turnover of TI institute users with the turnover of all companies in Norway, we would almost certainly find a clear positive difference between users and non-users that would largely be attributable to a poor choice of control group. We attempt to tackle the issue of selection bias in two steps, first by establishing a large pool of companies that engage in R&D, and then by using statistical techniques to match companies from the two pools (users and non-users), with only companies for which a match has been found being included in the final user and non-user groups.

Figure 33 schematically illustrates net impact (average treatment effect) calculated through a counterfactual approach. For example, we may calculate the change in users' turnover between collaboration with a TI institute at time t_0 and a later time t_1 (gross effect) and compare this with the change in non-users' turnover (over the same time period); the net impact attributable to the users' collaboration with TI institutes is the difference between the change in turnover for the users and for the non-users. However, the collaboration patterns are in reality considerably more complex than shown in the figure, since many companies have collaborated with more than one TI institute, and their collaboration has been of different intensity and has taken place during different time periods. Our econometric approach takes this into account, as we will later explain.

[26] "Central Innovation Manual on Excellent Econometric Impact Analyses of Innovation Policy". Ministry of Science, Innovation and Higher Education, Denmark, 2012.
"Dare to measure: Evaluation designs for industrial policy in the Netherlands". Final report of the Impact Evaluation Expert Working Group, Ministry of Economic Affairs, The Netherlands, 2012.

[27] G. W. Imbens and J. M. Wooldridge, "Recent developments in the econometrics of program evaluation", NBER Working Paper Series. Working Paper 14251, 2008. www.nber.org/papers/w14251.

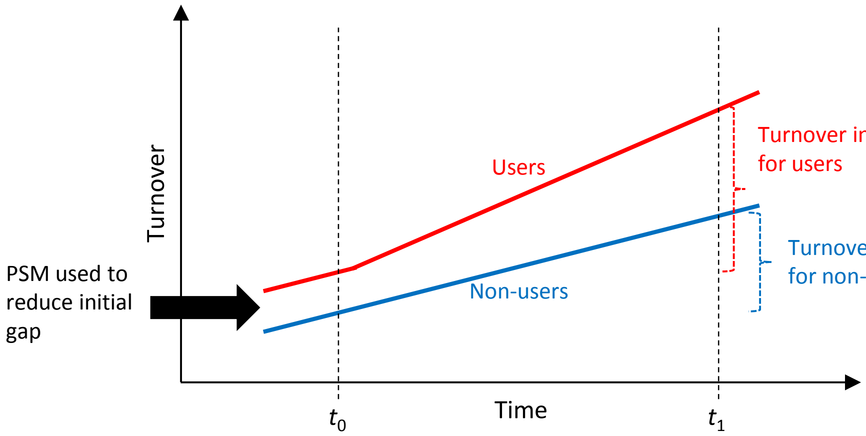

Figure 33 Schematic representation of counterfactual analysis.[28]

3.5.2 Data description and sources

The development of our user and non-user groups has made use of the three databases described in Table 10. Each database includes a large number of company records and each record includes the company's unique organisation number (legal registration number in Norway), which makes it straightforward to match and compare the datasets. Only companies with a Norwegian organisation number are included in the analyses, meaning companies that are based in Norway, including Norway-based subsidiaries of multinational corporations.

Table 10 Overview of databases provided by RCN. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

	Description	Period	Number of companies	Additional notes
RCN's data warehouse	Information on all projects co-funded by RCN	2005–2014	2,602 companies: • Users: 1,204 • Non-users: 1,398	The database contains information on 3,602 organisations. Of these, 2,602 are companies that have collaborated with other organisations, and 1,204 of these companies with at least one TI institute
RCN's SkatteFUNN database	Information on companies granted a tax relief for investing in R&D	2003–2015 (based on project start year)	10,269 companies: • Users: 3,541 • Non-users: 6,728	This database contains information on 10,404 companies, of which: • 3,541 collaborated with a TI institute • 135 collaborated with another organisation, but information on with which is lacking • 6,728 did not collaborate with another organisation, but obviously engage in R&D since they were granted a tax relief
Eniro's	Contains detailed	1998–2013	441,081	This database contains

[28] PSM stands for Propensity Score Matching, which is introduced later in the chapter.

	Description	Period	Number of companies	Additional notes
company database	financial information on all companies with operations in Norway		companies	information on more than 1,700,000 unique companies, but for most of them there is no information. After omitting these, 441,081 companies remain

3.5.3 Identification strategy

3.5.3.1 Defining treatment and control groups

We elected to construct our user and non-user groups using two databases rather than one, in order to take advantage of their slightly different profiles in order to arrive at a larger and more mixed pool of companies active in R&D. The extract from RCN's data warehouse is dominated by large companies, while the SkatteFUNN database has a higher proportion of small companies. Both databases include a large number of companies that have not collaborated with the TI institutes. The starting point for the user group is companies that (as a minimum):

- Have collaborated, as project leaders or partners, with a TI institute in a project co-funded by RCN
- Have been granted an R&D tax relief through the SkatteFUNN scheme and has bought services from a TI institute

For the non-user group, we used the two databases to identify companies that:

- Have collaborated, as project leaders or partners, in a project co-funded by RCN, but *not* with a TI institute
- Have been granted an R&D tax relief through the SkatteFUNN scheme but has *not* bought services from a TI institute (either because they have bought services from other organisations, or because they have carried out the R&D in-house)

We identified a total of 7,257 companies that satisfied these criteria. There is of course a possibility that some companies included in this group of non-users have collaborated with a TI institute in an earlier time period or through other collaborative instruments than those covered by the data extract provided by the RCN and SkatteFUNN databases, but it is not possible to overcome this limitation of the data. It is of course also possible that some apparent non-users have bought commissioned services, but never participated in any public instrument. In addition, some non-users may have bought services from other institutes in- or outside Norway. In conclusion, it is reasonable to assume that the group of non-users contains some false non-users, but we have reason to believe that they are a relatively few and thus do not greatly influence the results.

3.5.3.2 Interaction with TI institutes

To estimate changes over time in selected characteristics between users and non-users, we needed to identify a period before and after collaboration with the institutes took place. However, as alluded to above, there is no single year in which all user companies started collaborating or a single year in which collaboration ceased, because the "before" and "after" periods are specific to each user.

Figure 34 shows the distribution of years of first and last collaboration for the pool of 4,257 users. As mentioned above, our data on collaboration (from the RCN and SkatteFUNN databases) only cover the period 2003–2015. It is possible that some companies have collaborated with a TI institute in an earlier time period, but we are not able to identify these potential prior collaborations based on the available data.

Hence, in our analysis we use the term "first year of collaboration" to refer to the first collaboration that took place within the period 2003–2015.

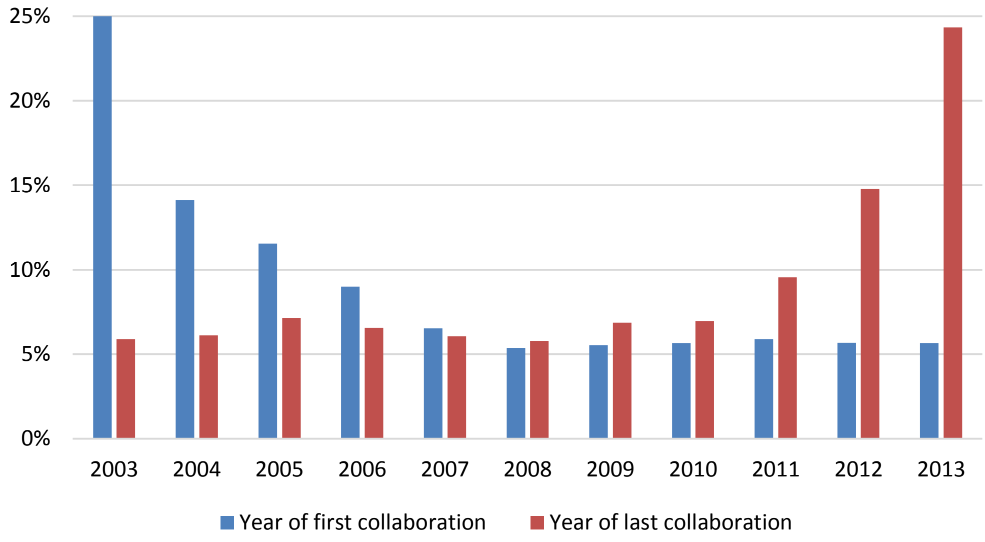

Figure 34 Distribution by year of first and last collaboration of users (N = 4,257). Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

The distribution suggests that there is a high level of turnover in the collaboration with the TI institutes, with several hundred companies entering into their first collaboration with an institute each year and a similar number apparently ending their collaboration (at least for the time being). The notion of turnover of users (and not just a continuously on-going collaboration) is important for our econometric strategy.

3.5.3.3 Matching of non-user and user companies

As already explained, a crucial aspect of this type of analysis is to ensure that users and non-users are comparable *before* participation takes place. Our identification strategy in part addressed this requirement by only including companies that are R&D active in the group of non-users. To further assure the comparability of both groups, we used a technique called Propensity Score Matching (PSM) to produce a set of matching pairs of companies from the user and non-user groups. PSM entails scoring every company in a series of characteristics in order to statistically compare scores between companies of the two groups to select good matching pairs. To improve matching, it is advisable to use as many characteristics as possible. In practice, the score is thus a composite of company characteristics.[29] In our analysis, we used company age, employment, turnover, productivity (defined as turnover per FTE), total equity, total liabilities and operating profit one year *before* the first collaboration took place. Since the "before" year is company-specific, we created an algorithm to select users in each year of first collaboration and to find a match from the group of non-users (in the same year).

Our matching strategy was successful in balancing the groups, and the exercise resulted in 2,657 users and 1,940 non-users, see Appendix A.4 for details. The

[29] M. Caliendo and S. Kopeinig, "Some Practical Guidance for the Implementation of Propensity Score Matching", Discussion papers series IZA DP No. 1588. IZA, 2005.

numbers differ because some non-users have been matched to more than one user. This is a large pool that, together with the fact that we had financial data for the period 1998–2013, provided a strong platform for the econometric analysis.

Following standard practice, we excluded companies with outlier values for turnover and productivity from the analysis. An outlier value is herein defined as being three standard deviations minus or plus the average value of the indicator in a given year. The figures provided above account for the exclusion of such outliers.

3.5.4 Econometric estimation

Once the sample has been "balanced" (using PSM), we proceeded to perform an econometric analysis using a fixed-effects model, which estimates how *changes* in characteristics or status (e.g. from not collaborating to collaborating) affect the outcomes of interest. The analysis focused on two performance indicators, namely turnover and productivity (the dependent variables in our models), to compare changes in averages for users and non-users, before and after collaboration with TI institutes take place (for users).

We accounted for different timeframes in which effect may materialise. Figure 12–Figure 14 indicate that for most companies it takes less than 5 years for the economic benefits of the collaboration with the TI institutes to materialise. In this exercise, we tested for a lag of one to five years to identify when the effect "kicks in", e.g. with a lag of three years, we study the effect in 2006 for companies that started collaborating with TI institutes in 2003. Many companies appear as users in several years, and our models account for all years in which collaboration took place.

Our approach is described in detail in Appendix A.5. In simple terms, we estimated the extent to which collaboration with the TI institutes (with an indicator as our explanatory variable) leads to an increase in turnover and productivity (dependent variables). We argue that this is a causal relationship (rather than a simple correlation) given that we compared this effect with a control group (which provided the hypothetical comparison of what would have happened to users had they not collaborated with TI institutes).

3.5.4.1 Turnover

The analyses detailed in Appendix A.5 shows that collaboration with TI institutes has indeed had a positive effect on users' turnover. This means that the intermediate impact on companies in terms of improved scientific and technical skills, implementation of new data, techniques, software etc., and expanded networks (cf. Figure 3 and Figure 8) also translates into additional turnover.

Figure 35 shows that, on average, users had a turnover that is 28 per cent higher than non-users one year after collaboration started, and the effect remained positive and statistically significant up to four years after the collaboration started. In the fifth year the effect became statistically insignificant (i.e. equal to zero). This means that, companies that collaborated with a TI institute in 2003 experienced a positive turnover development in the years 2004–2007 compared with non-users. Note that the results should be understood as a comparison of averages. It means that the group of non-users forgo, on average, 28 per cent in year one, 20 per cent in year two etc.

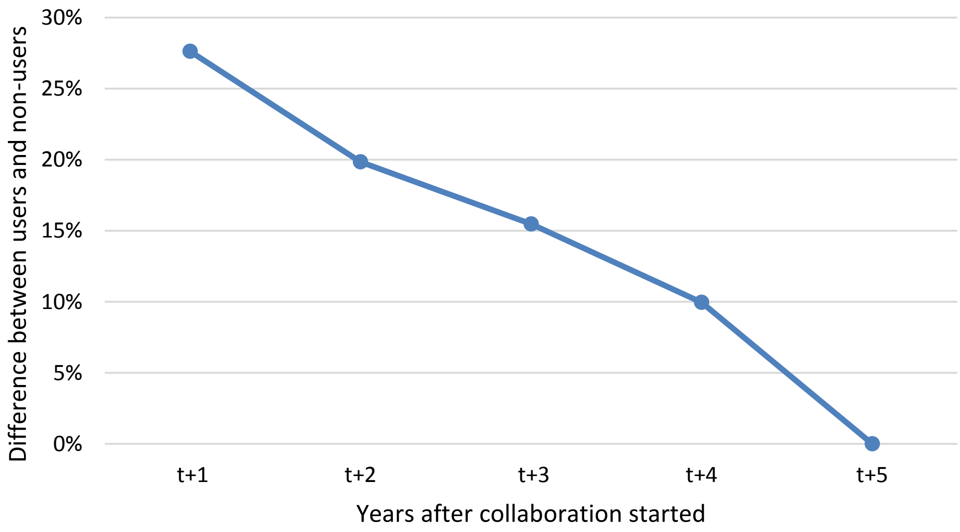

Figure 35 Effect on users' turnover in years after collaboration. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

As mentioned above, it is possible that some users have been classified as non-users, since they did not appear in the RCN or SkatteFUNN databases, but since it seems unlikely that we inadvertently should have misclassified only low-growth companies as non-users, this should not exaggerate the results. However, one could argue that a user's decision to collaborate with a TI institute is part of a general (and possibly aggressive) strategy to grow and improve productivity. If this is the case, we may not fully have succeeded in our intent to avoid selection bias, and the results of Figure 35 may thus in part be exaggerated. This is indeed a plausible explanation, which we cannot test with the data at hand. We return to this issue in Chapter 5.

The results in Figure 35 do not take into account differences in collaboration patterns, or intensity. To investigate potential differences due to collaboration intensity, we applied our model to two sub-samples; the first one only including users that had collaborated in one single year, the second one only including users that had collaborated in multiple years (both sub-samples including their respective matches among non-users). We found that the effect of collaboration on turnover was positive and statistically significant for one-time users in the first two years after collaboration started, see Figure 36, while multiple users enjoyed a more positive (and statistically significant) effect on turnover for four years. In the first year, the magnitude of the effect for multiple users is almost identical to that of the overall sample, but it is slightly larger in the following three years.

The figure also shows that five years after collaboration, the effect on one-time users is negative and statistically significant. A possible, albeit somewhat far-fetched, explanation for this puzzling result is that the competitors of one-time users were effective at "catching up" and closing the competitive advantage that the users had enjoyed in the previous years from their collaboration with a TI institute.

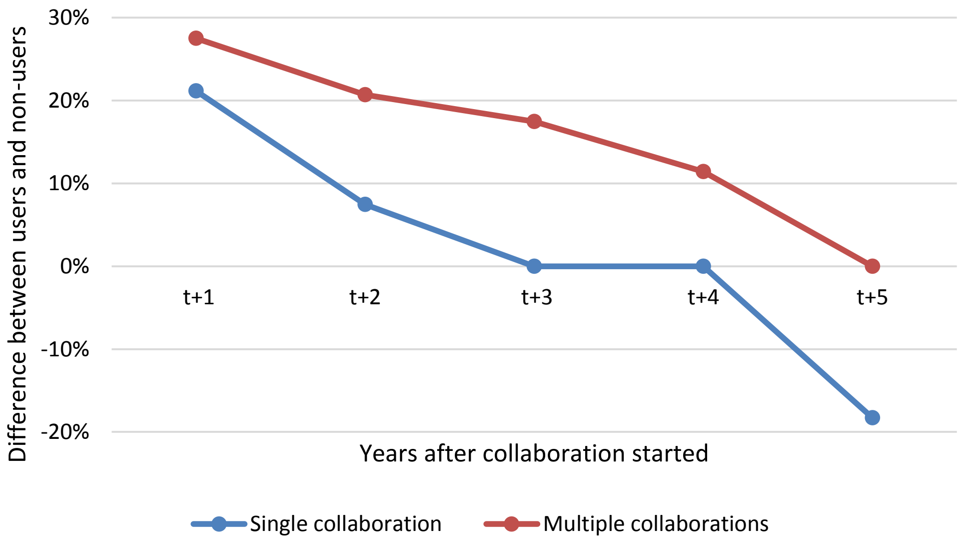

Figure 36 Effect on users' turnover in years after collaboration as function of collaboration intensity. Source: Technopolis econometric analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

Figure 37 shows the estimated aggregated (grossed-up) turnover development for the 2,657 users that are part of our econometric exercises (i.e. it excludes both outliers and companies for which a non-user match could not be found). The figure also shows a counterfactual scenario for the very same companies had they *not* collaborated with TI institutes (i.e. had they been non-users). The counterfactual scenario has been calculated by making a prediction at company level, based on the results obtained from the econometric analysis. In other words, the counterfactual scenario shown in the figure is not estimated by simply applying the average coefficients shown in Figure 35 and Figure 36, but by making individual estimations (predictions) at company level.

The difference between the curves thus illustrates the additional turnover attributable to collaboration with TI institutes. The observed and counterfactual trends are the same until 2003, since our data only includes collaboration that took place from 2003 onwards (and the first effect is thus observed one year later). The counterfactual trend shows the turnover development had the 2,657 user companies in our sample not collaborated with the TI institutes at all. It should be noted that not all companies existed the entire 1998–2013 time period, meaning that part of the turnover increase is due to the inclusion of additional companies.

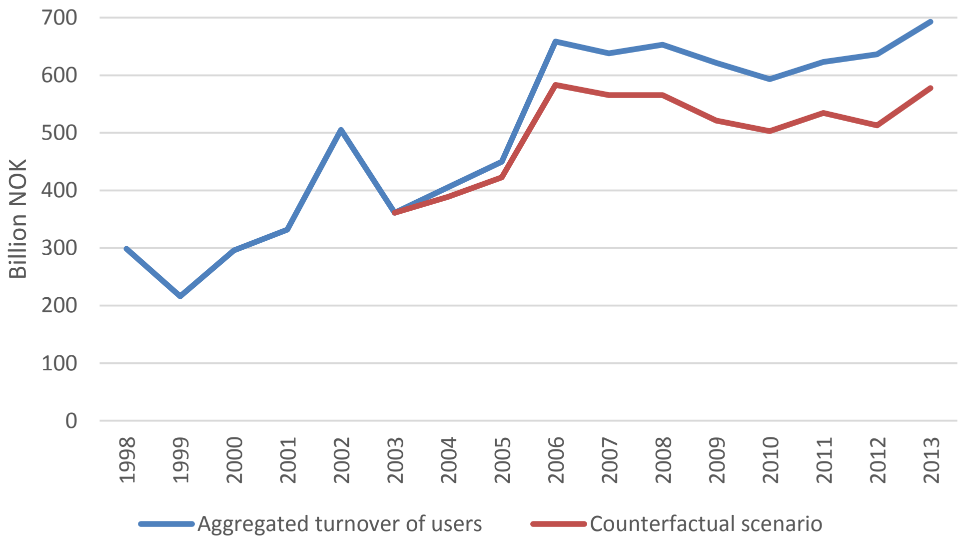

Figure 37 Effect on turnover for the 2,657 users of the econometric exercises (billion NOK, real prices 1998-fixed). Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

The additional turnover due to collaboration with TI institutes (the difference between the observed trend for the users and the counterfactual scenario) is estimated to a total of NOK798bn in the period 2004–2013 (real prices 1998-fixed). This represents 13 per cent of the total turnover of all users in our sample in that period (NOK5,972bn, real prices 1998-fixed). Table 11 presents the upper and lower bound estimates of both the additional turnover and the percentage that this additional turnover represents in comparison with the total turnover of all users in our sample. These lower and upper bounds are calculated based on the standard errors of our estimations (at company level) and are based on a 95% confidence level (i.e. we can be 95% certain that the additional turnover lies between NOK711bn and NOK884bn).

Table 11 Lower and upper bound estimates (based on a 95% confidence interval). Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

2004–2013	Upper bound	Estimate	Lower bound
Additional turnover (billion NOK)	884	798	711
Percentage of total turnover	15%	13%	12%

3.5.4.2 Productivity

We used a similar approach as the one for turnover above to investigate the effect of collaboration on the (logarithm of) productivity (turnover per FTE). As illustrated by Figure 38, there is a positive effect also in terms of productivity. On average, users have a level of productivity that is 5.5 per cent higher than non-users one year after collaboration started. Analogously, non-users forgo 5.5 per cent in potential productivity gains in that year. The figure also shows that the positive effect on users' productivity disappears after three years.

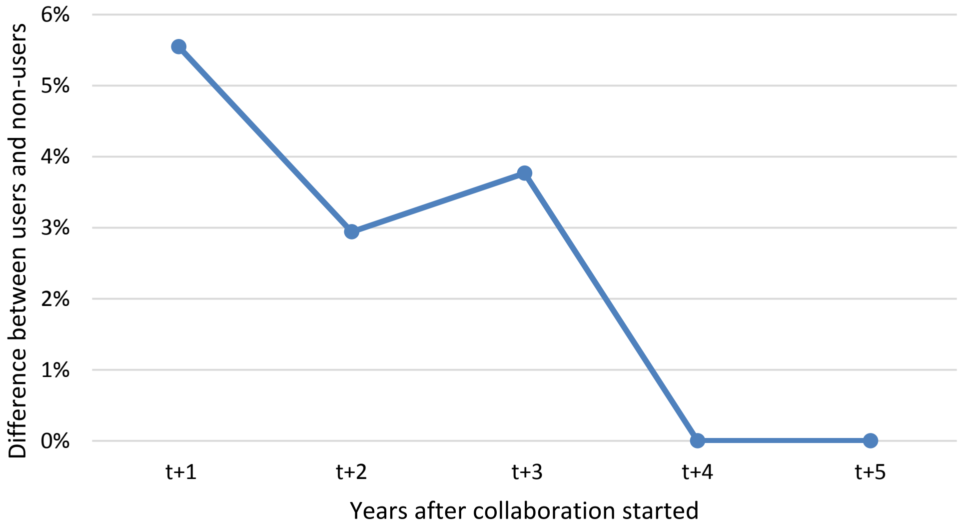

Figure 38 Effect on users' productivity in years after collaboration. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

We also investigated potential differences due to collaboration intensity, but found that the effect on one-time users is not statistically significant (i.e. equal to zero) even in the first year following collaboration. However, the effect is positive and statistically significant for multiple users during the first three years, see Figure 39. Again, as for turnover, the effect for multiple users is larger than for the overall sample; multiple users experienced a productivity gain of 6.7 per cent on non-users in the year after collaboration.

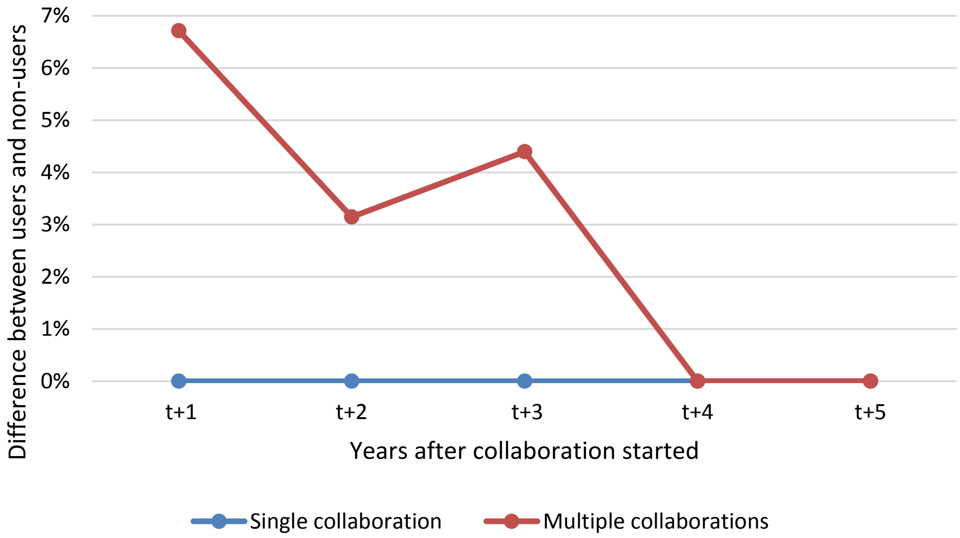

Figure 39 Effect on users' productivity in years after collaboration as function of collaboration intensity. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

4. Scientific impact

This chapter is a summary of the bibliometric analysis subproject that in depth is separately reported.

The output of the TI institutes in terms of scientific publications has been analysed through a comprehensive bibliometric study. This analysis focuses on productivity of the institutes, their publication profile, the scientific impact of the research as reflected trough citation indictors, as well as their collaboration patterns, analysed through co-authorship. Included in the analysis are publications that have been published by the staff at the institutes during the period 2009–2013, and which are credited to the institutes through the Norwegian performance-based funding system. This means that the analysis covers publications in recognised publication channels, but not other types of output such as grey literature and reports.

There are large differences among the institutes in the volume of scientific publishing. The SINTEF Foundation is the major contributor and accounts for 41 per cent of the scientific publishing of the TI institutes measured as publication points during the period 2011–2013. When including the associated institutes of the SINTEF Group, MARINTEK, SINTEF Petroleum Research and SINTEF Energy Research, this proportion increases to 62 per cent. SINTEF Materials and Chemistry and SINTEF Energy Research are the largest single institutes with proportions of 18 and 16 per cent of the total publication output of the TI institutes, respectively. Then follows SINTEF ICT with a proportion of 13 per cent. IFE is the fourth largest institute with a proportion of 10 per cent. The smallest institutes in terms of scientific publishing, CMR, Tel-Tek and Norut Narvik, have proportions of 1 per cent each.

There are also significant differences among the institutes in how large a part of the R&D activities that result in scientific publications. This can be measured by dividing the publication points by the number of researcher full-time equivalents (FTEs). In the period 2011–2013, SINTEF Energy Research has the highest ratio, 0.89 publication points per FTE researcher, followed by NORSAR with 0.78 and NR with 0.66. CMR, MATRINTEK and SINTEF Petroleum Research have the lowest publication productivities, with 0.19–0.24 publication points per researcher FTE. The figures reflect that the institutes are a very heterogeneous group in terms of R&D activities. Some institutes have a much stronger focus on basic research, which is more likely to result in scientific publications. Others have a profile dominated by services and technology development, where scientific publishing is less relevant.

During the period 2009–2013, there was a marked increase in the volume of scientific publishing. Overall, the TI institutes increased their number of publication points by 26 per cent during the period. It is likely that the performance-based funding system, where scientific publishing counts as one of the indicators, has functioned as an incentive to increase publication activities.

The scientific profile of the institutes have been analysed using data on the subfield distribution of the publications. This analysis is based on publications indexed in Web of Science (WoS) only. Accordingly, it covers only a part of the research output, i.e. the portion that has been published in international journals.

The analysis shows that the TI institutes have a very strong specialisation in Geological engineering, Petroleum engineering and Ocean engineering. We also find strong specialisation in Energy and Fuels, Construction & building technology as well as Marine engineering. On the other hand, relatively speaking the institutes have little research output (a negative specialisation) within several engineering subfields, for example, Electrical & electronic engineering, Mechanical engineering and Nanoscience & Nanotechnology.

The TI institutes have contributed to 55 per cent of the total Norwegian publication output in Geological engineering during the period 2009–2013. The proportions are also very high in Construction & building technology (47 per cent) and Metallurgy &

metallurgical engineering (45 per cent). These are subfields where the TI institutes have key roles as contributors within the Norwegian R&D system. There are additional areas where the institutes are large, but less prominent, contributors with proportions in the range of 30–40 per cent of the national total, such as Material science, Electrochemistry, Petroleum engineering, and Energy & fuels.

Data on the extent to which publications have been cited, in the subsequent scientific literature can be regarded as a proxy for the scientific impact of the research. The citation analysis is also limited to the WoS indexed articles and covers the period 2009–2012. Overall, the TI institutes obtain a citation index of 120, which means that the articles have been cited 20 per cent more frequently than the field-normalised world average. This is marginally above the Norwegian average within Engineering science, which is 117. Accordingly, the TI institutes overall perform reasonably well when it comes to scientific impact measured through citations.

There are, however, large differences at the level of subfields. In two subfields, the publications of the TI institutes are extremely highly cited: Petroleum engineering and Construction & building technology, with citation indices of 340 and 293, respectively. The institutes also perform very well in Civil engineering (169) and Metallurgy & metallurgical engineering (147), where citation indices are far above the world average. On the other hand, there are many subfields where the citation index is significantly below the world average, for example, Physics, condensed matter and Nanoscience & nanotechnology with citation indices of 44 and 59, respectively. Several of the subfields with high citation indices are also areas where the TI institutes have a high specialisation, for example Petroleum engineering, Construction & building technology and Metallurgy & metallurgical engineering.

There are also large differences in citation indices between individual institutes. SINTEF Building and Infrastructure obtains the highest citation index with 192. Then follow Uni Research with 164, IRIS with 162 and MARINTEK with 140. These institutes perform very well in terms of citation rates. On the other hand, there are several institutes with citation rates significantly below the world average. In particular, the citation indices are rather low for Norut Narvik (49), Tel-tek (71), NORSAR (74) and CMR (74). When interpreting the figures, it is important to emphasise that citations mainly reflect intra-scientific use. Practical applications and use of research results will not necessarily be reflected through citation counts. Moreover, due to various limitations and biases attached to citation indicators, they cannot replace an assessment carried out by peers.

The analysis shows that the TI institutes are heavily involved in scientific collaboration. This is reflected in the fact that many publications have co-authors from other institutes, institutions and industry. Almost half of the publications have been published with co-authors from foreign institutions. In addition, there is extensive national collaboration. There are particularly strong collaborative links between the TI institutes and the Norwegian University of Science and Technology (NTNU). In fact, approximately one third of the publications from the period 2011–2013 had co-authors from NTNU. The institutes within the SINTEF group account for the majority of these publications, but there are also many publications from other institutes. The University of Oslo (UiO) is by far the largest university in Norway and ranks as the second most important institutional partner of the TI institutes. In total, 9 per cent of the publications had co-authors from Norwegian companies. The incidence of scientific publishing in industry is generally very low. This is partly due to the commercial interest related to research results, which means that the results often cannot be published, i.e. made public. Therefore, only a limited part of the institutes' collaboration with industry is reflected through co-authorship data.

5. Reflections

This report merges the findings of three impact sub-studies, where the emphasis lies on two, a qualitative study based on the opinions and perceptions of TI institute users, and a quantitative study that relies entirely on analyses of available databases. The qualitative study is thus clearly subjective and we know that the users polled have a positive bias (but not the extent of it). In contrast, the quantitative study is in principle objective, but it is not free from selection bias (we return to this later on in this chapter). The qualitative study mainly focuses on *through what mechanisms* and *in what time frames* that economic impact eventually may emerge for an organisation as a result of collaboration with a TI institute as client or partner. This study addresses impact on both private companies and public organisations. The quantitative study focuses entirely on various aspects of economic impact, both on society at large and on user companies, thus providing *quantified estimates of economic impact* through different impact streams. While the two sub-studies consequently are very different, they complement each other well.

On how collaboration may lead to impact

The qualitative study illustrates that the TI institutes play an important role in providing expertise, facilities and networks to users of all types. For some companies, the institutes are said to play a very important role. In many cases, companies and different types of public-sector organisations become recurring clients and partners, and several establish long-term strategic relationships with a TI institute to ensure recurring access to its expertise and facilities. The main underlying reason for this is that clients and partners realise, or at least believe, that collaboration will increase their own competitiveness, often seen from an international perspective. For many, it is apparently difficult to know for sure whether such impact actually does result, but one interview quote sums up a recurring sentiment: "We hope that our collaboration eventually will yield profit, otherwise we would not have started collaborating."

It is beyond the scope of this study to understand and describe the detailed mechanisms through which collaboration with a TI institute may lead to economic impact, but the empirical data nevertheless provides some clues. Collaboration with institutes on the one hand provides users with access to scientific and technical expertise, as well as hardware and software infrastructure, that they do not have themselves. Thus far, it may be a matter of buying consultancy services (commissioned work), but most users also develop the skills and expertise of their own personnel to ensure that they can solve some of their future problems in-house, and to become more qualified as clients and partners. A particularly powerful way for users to increase their own competences is to recruit researchers from institutes or their university partners. Norwegian partners see notably stronger impact than foreign ones in terms of recruitment of researchers, which seems natural. For obvious reasons, foreign organisations find it more difficult to recruit researchers from a Norwegian R&D performer. As mentioned above, it is common that collaboration has a certain degree of continuity, and long-term collaboration makes for both more comprehensive and more profound knowledge and technology transfer. Long-term collaboration also facilitates forming of competitive partnerships or consortia for future proposals for R&D projects. Much of the continuity is thus part-funded by public R&D funding agencies, such as RCN and EU's Framework Programme, as well as by the SkatteFUNN tax relief scheme. Without such public "fuel", there would be much less continuity in the collaboration between users and TI institutes, and thus much less economic impact. This is a classic and well-established example of a "market failure".

On time lags between collaboration and impact

While some commissioned work may be more or less directly implementable in companies', particularly SMEs', commercial operations, it is considerably more common that collaboration provides one of many inputs to a future change in a user's commercial or public operations, meaning that there is a time lag. Based on previous studies, we initially formulated the hypothesis that as clients, users buy services from institutes to solve a specific problem and they generally expect to be able to implement the results in the short term. As partners, they often collaborate to develop new knowledge that may possibly be used to improve products and processes sometime in the future, and the expectations for economic impact are consequently vaguer.

The empirical data largely verifies the hypothesis. The expected time lag to economic impact is much shorter for both SMEs and large companies when they are clients. Moreover, SMEs see notably greater impact in terms of increased international competitiveness, turnover and exports when they are clients; the greater impact observed is surely a result of the work commissioned having been straightforward to implement in the company's commercial operations. Commissioned work tends to be targeted to a specific, and often pressing, company need (e.g. input to a company's on-going product development), whereas collaborative R&D projects to a greater extent tend to deal with creation of new knowledge and implementation of new techniques, meaning that the time lag to economic impact is obviously much longer. Moreover, the topic of a collaborative R&D project is almost always a compromise among different organisations' desires, and it is often in practice defined by an institute (or an HEI), meaning that the project by default will be less "spot on" for a specific organisation's needs. The empirical data for large companies does not provide an equivalent difference for the extent of impact.

The existence of a time lag between collaboration with an institute and observable commercial impact is an important message, and it is in agreement with many ambitious impact assessments of long-term collaborative R&D programmes that indicate that development times from R&D results to commercial reality indicatively may range from 5 to 20 years depending on industry, product, application etc.[30] At the far end, we find the aerospace industry with up to 20 years[31], while time lags in the automotive industry[32] and in manufacturing industry in general[33] appear to be on the order of half as long.

On economic impact according to users

More than half of SMEs, and more than a third of large companies, agree that buying R&D services from a TI institute contributes, or is expected to contribute, to increased turnover for the company. This is good news, but we need to keep in mind that the survey respondents are indeed a positive selection of clients, and we should thus refrain from extrapolating such impact to the wider population of TI institutes users. Even in this positive selection there are of course respondents that strongly disagree to

30 L. Elg and S. Håkansson, "Impact of Innovation Policy. Lessons from VINNOVA's impact studies", VINNOVA, VA 2012:01, 2012.

31 T. Åström, T. Jansson, P. Mattsson, H. Segerpalm and S. Faugert, "Evaluation of the Swedish National Aeronautics Research Programme – NFFP" ("Utvärdering av det Nationella flygtekniska forskningsprogrammet – NFFP"), VINNOVA, VR 2008:05, 2008

32 S. Faugert, E. Arnold, M.-L. Eriksson, T. Jansson, P. Mattsson, L. Niklasson, P. Salino, H. Segerpalm and T. Åström, "Impact of Government Support to Automotive Research", ("Effekter av statligt stöd till fordonsforskning – Betydelsen av forskning och förnyelse för den svenska fordonsindustrins konkurrenskraft", VINNOVA, VA 2009:02, 2009.

33 T. Åström, T. Jansson, P. Mattsson, S. Faugert, J. Hellman and E. Arnold, "Impact Analysis of Support for Strategic Development Areas in the Swedish Manufacturing Industry" ("Effektanalys av stöd till strategiska utvecklingsområden för svensk tillverkningsindustri"), VINNOVA, VA 2010:05, 2010.
T. Åström, J. Hellman, P. Mattsson, S. Faugert, M. Carlberg, M. Terrell, P. Salino, G. Melin, E. Arnold, T. Jansson, T. Winqvist and B. Asheim, "Impact Assessment of Strong Research and Innovation Systems" ("Effektanalys av starka forsknings- och innovationssystem"), VINNOVA, VA 2011:07, 2011.

any impact at all on turnover, and if we had had responses from more clients that never returned after their first experience, there would have been more of them.

When they are partners, the percentage of respondents that agree that working with a TI institute has contributed, or is expected to contribute, to increased turnover is approximately 10 per cent lower. This is fully in line with the discussion in the previous section on time lags; collaborative R&D projects generally address long-term issues, and they are almost always a compromise among different organisations' desires.

The degree to which respondents agree to increased turnover and exports may seem somewhat low; why are companies then repeat clients and partners? There are many possible, and probably complementary, answers to this question. One reason may be that companies are content not to grow as long as they can maintain a decent bottom line (not uncommon with owner-led SMEs), or that the reasonably high ratings of impact in terms of more efficient internal processes and decreased costs translate into improved results despite turnovers not increasing. Another reason, which is well-known to evaluators, is that respondents do not attribute a certain impact to the intervention under study (in this case increased turnover as a result of collaborating with a TI institute). This may either be intentional ("we achieved this on our own", i.e. the common not-invented-here syndrome), or unintentional, because the respondent does not see the connection between intervention and impact. The unintentional non-attribution in terms of commercial impact is particularly common in large companies where researchers and engineers often have very limited insight into what the marketing and sales departments do, and where and how their own contributions may fit in. Judging from previous experiences, this is probably the reason why SME respondents are more positive as regards impact on turnover and exports than large companies; it is often more easy to understand, and have an overview over, the operations of an SME, particularly for respondents and interviewees that are often the managing director or the individual responsible for R&D.[34] In light of such circumstances, the percentages of respondents that agree to increased turnover and exports are not low. Fortunately, the quantitative study provides an opportunity to go beyond users' (subjective) statements; we return to that below.

Few client respondents (4 or 5%) appear to believe that new companies have been spun off as a result of the relationship with a TI institute, but notably more partner respondents do so (30 or 8%). While these responses should be taken with a grain of salt, it seems logical that the incidence of new companies should be higher from collaborative R&D projects that (mostly) engage in multi-year endeavours to create new knowledge and techniques. This is likewise good news, but we need to recall that also partner respondents are a positive selection (although less so than client respondents), and that attribution of collaboration to the establishment of a spin-off company is probably very seldom unambiguous. Moreover, we do not know whether the spin-off companies that respondents have in mind are ones established by (former) employees of a TI institute or of the respondents' organisations, or a combination. It is nevertheless likely that some of them are among the 117 spin-off companies of the TI institutes, which we also return to below.

On leveraging government funding

Overall, the TI institutes are good at leveraging national public funding. The institutes have received NOK10bn in Norwegian public funding in the period 1997–2013, and have managed to attract an additional NOK34bn in income from other sources,

34 T. Åström, K. Henningsson and A. Håkansson, "Swerea SICOMP: Impact assessment of the RTO's activities 1989–2014", Swerea Group, 2014.

translating into an overall ratio of 3.4.[35] We have also found that an increase in Norwegian public funding results in an increase in income from other sources in the future (rather than leading to a decrease or a replacement), and vice versa. Thus, a hypothetical 10 per cent decrease in Norwegian public funding is met with a 2.9 per cent decrease in funding from other sources two years later.

However, it is a disconcerting fact that the ratio of Norwegian public funding and income from other sources has fallen sharply since 1997 due to a decreasing share of income from Norwegian industry and a simultaneously increasing share of income from RCN. This trend of diminishing return on public funding could indicate that the institutes are becoming less relevant to industry, or possibly just that they are outgrowing the Norway market and find it easier to increase income from RCN and foreign sources than from Norwegian industry. Either way, the diminishing return on public investment and the decreasing share of income from Norwegian industry are certainly issues to monitor and for RCN to strive to better understand, in order to fulfil its task to “take strategic responsibility for the research institute sector”. Nevertheless, the fact that half of total turnover in 2013 came from private commissions (39 percentage points from Norwegian companies and 11 from foreign), and another 9 per cent from Norwegian public commissions, is an indication that the TI institutes are still relevant and competitive.

However, the income from Norwegian companies is known to be inflated in RCN’s statistics, since part of this income is in effect of public origin; through RCN’s IPN instrument and the SkatteFUNN scheme, companies frequently subcontract part of the (publically co-funded) R&D work to TI institutes. Unfortunately, RCN’s statistics do not include information on how much of the income from Norwegian companies that is in fact public, but according to RCN the share is “significant”. This means that the leverage ratio and the share of income from Norwegian companies should be taken with a grain of salt.

A fifth of the TI institutes’ turnover was foreign in 2013 (of which 15 percentage points were from private sources and 5 from EU programmes). This is a considerably higher share than for the German Fraunhofer Group (FhG), but much lower than for the Danish GTS Group (which in all fairness is extraordinarily successful in this respect), see Figure 40. More worrisome is that the TI institutes’ export share has increased only 10 percentage points over the last decade, whereas the Fraunhofer Group’s has increased by 61 percentage points and the GTS Group’s by 36 percentage points. In this respect, the TI institutes are obviously losing ground to their foreign competitors.

35 Just as in previous chapters, all NOK amounts in this chapter are stated in real prices 1998-fixed.

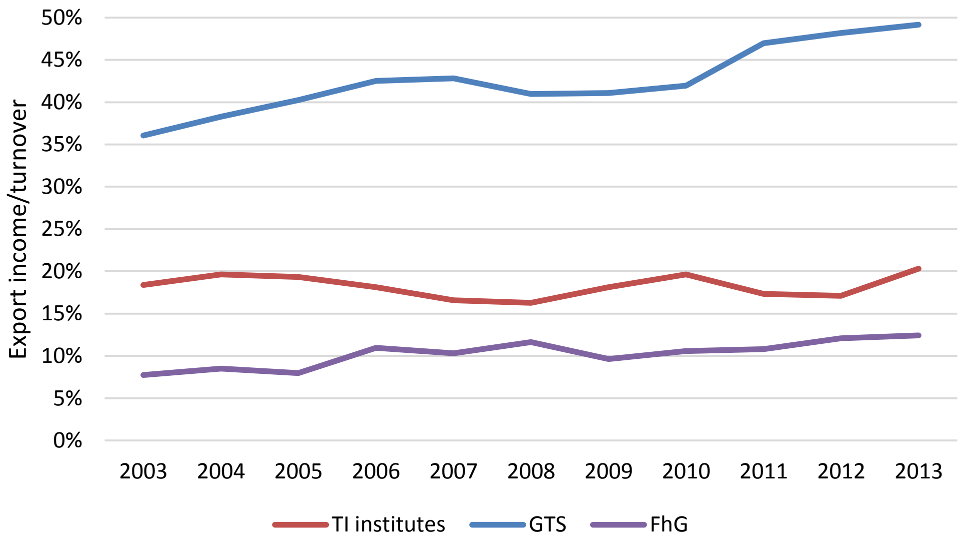

Figure 40 Export share of turnover for the TI institutes, the Danish GTS Group and the German Fraunhofer Gesellshaft (FhG). Source: Technopolis analysis of institute annual reports.

Figure 41 reveals that the TI institutes have considerably lower base funding than many of their foreign competitors. Some of these differences may possibly be attributed to the other institute systems having different missions and responsibilities, and being obliged to use parts of their base funding to carry out certain tasks. However, it is an unavoidable conclusion that the TI institutes are disadvantaged when it comes to the level of their base funding. An institute's base funding is its main source of funding to develop new knowledge and competences to satisfy tomorrow's user needs. An institute's base funding is also used to co-fund its participation in FP and Horizon 2020 projects, which are also means to develop knowledge and competence.

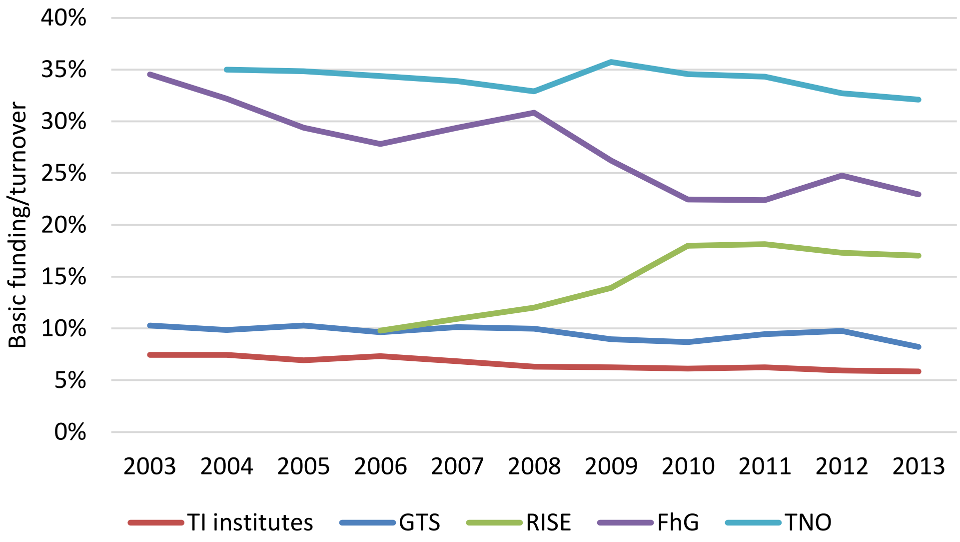

Figure 41 Base funding as share of turnover for the TI institutes and four other European institute spheres. RISE gathers the leading Swedish technical research institutes and TNO is the Netherlands Organisation for Applied Scientific Research. Source: Technopolis analysis of institute annual reports.

Is then the relatively modest level of foreign income a result of the low level of base funding? Perhaps not to the extent one might expect. Several TI institutes, notably ones of the SINTEF Group, do very well in the FP, and a previous study argues that the meagre base funding may indeed function as a motivator to explore all available funding opportunities, including the FP.[36] Moreover, RCN has an instrument (STIM-EU) that specifically rewards, i.e. retroactively co-funds, institutes that participate in the FP. While this instrument is not limited to the TI institutes, they strongly dominate among recipients, and the SINTEF Group strongly dominates among the TI institutes. Even so, there is little doubt that the low level of base funding indeed limits the TI institutes' FP participation.[37] It is thus evident that the base funding makes it more difficult for the TI institutes, and in the long run also their clients and partners, to stay ahead of the international competition.

On economic impact according to quantitative analyses

We have explored the economic impact of the TI institutes through four different impact streams: (i) direct economic value creation; (ii) indirect and induced economic impact; (iii) economic value created through licensing, patenting and spin-off companies; and (iv) wider economic impact and knowledge spillover effects. It should be noted that for lack of data, these analyses do not include Uni Research.

The impact generated by the economic activity of the TI institutes, i.e. the first two impact streams (direct, indirect and induced effects), is estimated to NOK37bn in the period 1997–2013.

36 T. Åström, T. Jansson, G. Melin, A. Håkansson, P. Boekholt and E. Arnold, "On motives for participation in the Framework Programme", Norwegian Ministry for Education and Research, 2012.

37 T. Åström, A. Håkansson, G. Melin, P. Stern, P. Boekholt and E. Arnold, "Impact evaluation of the Research Council of Norway's support measures to increase participation in EU-funded research" («Effektmåling av Forskningsrådets støtteordninger for økt deltakelse i EU-finansiert forskning»), NFR, 2013.

The impact created through the third impact stream, i.e. the value generated through the exploitation and commercialisation of the institutes' research, may be divided into three parts; economic value created through licensing, patenting and spin-off companies.

- The institutes' income from licensing has been a mere NOK207m in the years 1997–2013, which is obviously marginal in relation to the institutes' total income
- In the period 1997–2013, the TI institutes have, according to themselves, filed over one thousand patent applications, but fewer than 400 have been found in PATSTAT. One possible explanation is that PATSTAT registers EPO patent applications once only (and not one time for each country). Although the economic impact of the knowledge created by the TI institutes and codified in patent applications cannot be quantified, some of this new knowledge has certainly translated into increased competiveness and efficiency gains for Norwegian companies
- The economic impact of the 117 spin-off companies reported by the institutes is estimated to NOK11bn in the period 1997–2013 (equal to the companies' turnover). The 81 spin-off companies found in the Eniro database have had just above 600 employees since 2009. The group of spin-off companies is highly dominated by one most successful company (Electromagnetic Geoservices)

The econometric exercise to estimate the effects that the TI institutes have had on their users suggests that users, on average, experience a higher turnover than non-users for four years after collaboration started. For one-time users, the effect is lower and disappears sooner. The effect on productivity (turnover per FTE) is notable for three years for multiple users, but there is no effect for one-time users. Given the methodology used (econometric counterfactual analysis), we argue that the strong positive difference between TI institute users and non-users is at least in part attributable to users' collaboration with the institutes (we return to this below).

The impact created through the fourth impact stream is estimated to NOK800bn of additional turnover that in the period 2004–2013 has been generated in the Norwegian economy as a result of the collaboration between user companies (only the ones included in the econometric exercise) and TI institutes. This substantial additional economic output is equivalent to a total turnover for the ten-year period that is 14 per cent higher than for the counterfactual scenario wherein the very same companies have *not* collaborated with any of the TI institutes.[38] While NOK800bn undeniably is a very large number, it should be borne in mind that this is the additional turnover for more than 2,600 companies and over a decade. The figure is perhaps more comprehensible when considering that it represents 1.1 per cent of the total turnover of all Norwegian companies in the same time period. Nonetheless, the figure is perhaps best thought of as additional economic output that would not have been realised without the TI institutes, but which is also the result of complementary investments by user companies and therefore is not attributable in full to collaboration with TI institutes.

[38] While we feel a need to be very cautious in our interpretation of the magnitude of the additional turnover generated by the user companies included in the econometric exercise, it should be noted that the estimate is simultaneously an under-estimation for two reasons. Firstly, the estimate excludes both outliers and companies for which a non-user match could not be found. Secondly, the data only includes collaboration that took place from 2003 onwards (and the first effect thus is observed in 2004), whereas the other impact streams go back to 1997.

Reflections on the results of quantitative analyses

The estimated average effect on turnover for users one year after the collaboration started (28%, on average) is very high, and its gradual reduction over the following three years is counter-intuitive. This has caused the study team to thoroughly reflect on the veracity of the counterfactual analysis. Micro-economic studies of collaborative R&D show commercial effects lagging projects by several years and then building gradually over several more years before declining. Paradoxically, in our econometric analysis the distribution of effects over time starts high and then declines, suggesting that our estimate is capturing effects deriving from users' purchases of short-term technical consultancy services (perhaps in combination with long-term R&D collaboration).

We are confident that the model (and the sample size) that we have used is robust and appropriate for the analysis. However, the company data available is not free from limitations, and the control and treatment (non-user and user) groups can therefore only be matched on a limited number of attributes. One of the main assumptions of the model is that the main factor that distinguishes users from non-users is their status of collaboration with TI institutes, while other characteristics remain similar (at least until collaboration takes place). However, we cannot reasonably control for other more dynamic qualities that may typify users; one could imagine that a user's decision to collaborate with a TI institute is part of an aggressive growth strategy and/or one to increase productivity. Hence, other investments, and in particular additional R&D investments, may have accompanied the purchase of services from the institutes or their collaboration in R&D projects. The effect of such complementary investments would be captured in our estimate of additional economic output and it is quite possible that the group of non-users does not mirror such a broader endeavour, in which case we are overestimating the value that is attributable to collaboration with the TI institutes. In conclusion, it is entirely possible that some element of selection bias remains in our sampling, with users somehow having a greater propensity for growth than non-users. As a result, at least part of the large estimated additional turnover is probably due to the qualities of the users rather than their collaboration with the TI institutes, but their growth is certainly enabled and facilitated by the collaboration.

Furthermore, it is quite possible that some users have been classified as non-users, since they did not appear in the RCN or SkatteFUNN databases, but since it seems unlikely that we inadvertently should have misclassified only low-growth companies as non-users, this should not exaggerate the results, rather the opposite.

Ideally, we would have been able to include several additional variables in our matching exercise, and in particular the level of R&D investment. Unfortunately, while the available databases can help us to distinguish R&D-active companies from non-R&D-active companies with a fair degree of accuracy, we do not know how much companies spend on R&D and whether there are substantial differences between users and non-users in this respect. However, even if we had been able to control for R&D expenditure, it might have been insufficient, as users do not only collaborate in R&D projects, they also buy technical services from the institutes. The knowledge and solutions acquired through the institutes could also have been met with additional investments not related to R&D (e.g. product design, marketing activities etc.).

It is worth noting that the same methodology that we have used recently was applied in a similar context and using similar data sources to produce similarly large positive effects. In a study for the European Commission, a consortium led by EIM Panteia (and with participation from Technopolis), analysed the effect among SMEs that participated in the FP7 Cooperation programme (and in FP6, to cope with expected time lags). The study, which employed counterfactual analysis and PSM to construct control groups, found a 30 percentage point difference in turnover growth rates between participants and non-participants. Just like our analyses, this study did not control for levels of R&D expenditure (or additional investments), the effects of which thus are likely to have been captured in the estimates.[39]

Parting words

The qualitative and quantitative sub-studies paint a coherent picture. The TI institutes play a very important role in the Norwegian innovation system, and the direct and indirect economic impact that they generate is of great importance to Norway and to Norwegian companies and public organisations.

From an international perspective, RCN has access to enviable amounts of information on Norwegian companies, from time series on financial data to information on companies' collaborative R&D behaviour. This data availability supports robust econometric analysis and allows estimation of the very substantial additional economic output made possible by the activities of the TI institutes. However, we judge that this large impact is not fully attributable to TI institute collaboration, and that some proportion of the increased output estimated is due to users' own qualities, probably including complementary investments. However, it is reasonable to conclude that the TI institutes have been a critical element in facilitating the estimated 1.1 per cent expansion of industry turnover within the Norwegian economy in the last decade.

[39] K. van Elk, J. Snijders, Y. Prince, P. Gibcus, S. Doove, P. Simmonds, K. Warta, B. Good, S. Ruhland and S. Sheikh, "Performance of SMEs within FP7. An Interim Evaluation of FP7 components", European Commission, 2014.

Appendix A Methodological notes

A.1 Econometric exercise on leverage

We used a log-log model for this exercise, i.e. a model that uses log transformations of the dependent and independent variable of interest. The models can be described using the following notation:

$$\ln(ext_{it}) = \beta_0 + \beta_1 \ln(int_{it-1}) + \beta_2 FTE_{it} + \beta_3 Institutes_i (= 1) + \varepsilon_{it} \text{ (Model 1)}$$

$$\ln(ext_{it}) = \beta_0 + \beta_1 \ln(int_{it-2}) + \beta_2 FTE_{it} + \beta_3 Institutes_i (= 1) + \varepsilon_{it} \text{ (Model 2)}$$

Where:

ext_{it} represents the value of funding obtained form external sources (business and abroad) for institute *i* in time *t*

int_{it} represents the value of funding obtained from public sources (RCN, ministries and other national sources) for institute *i* in time *t*

FTE_{it} represents the number of employees for institute *i* in time *t*

$Institutes_i$ is a set of dummy indicators that take the value of 1 for each institute. This variable captures ant variance in the result that comes from the institutes themselves.

ε_{it} is the error term for institute *i* in time *t*

The main result from this exercise is provided by the coefficient β_1, which have to be transformed for final interpretation. To show this transformation, we take two values of internal sources of income, *int1* and *int2*, and hold the other predictor variables at any fixed value. The equation(s) above yields:

$$\ln(ext\ 2) - \ln(ext\ 1) = \beta_1 \ln(int2) - \beta_1 \ln(int1)$$

$$\ln\left(\frac{ext2}{ext1}\right) = \beta_1 \left(\ln \frac{int2}{int1}\right)$$

Applying an exponential to both side of the equations we obtain:

$$\frac{(ext2)}{(ext1)} = \left(\frac{int2}{int1}\right)^{\beta_1}$$

This means a 10 per cent increase in internal sources (from *int1* to *int2*) (right hand side of the equation) equates to $1.10^\wedge\beta_1$ increase in external sources in the future (or $(1.10^{\beta_1} - 1)x100$ in percentage terms).

A.2 IO tables and multipliers

The output multiplier for an industry is expressed as the ratio of direct and indirect (and induced, if Type II multipliers are used) output changes to the direct output change due to a unit increase in final demand. So, multiplying a change in final demand (direct impact) for an individual industry's output by that industry's Type II output multiplier will generate an estimate of direct, indirect and induced impact upon output throughout the Norwegian economy.

$$Output\ multiplier = \left(\frac{direct\ sales + indirect\ sales + induced\ sales}{direct\ sales}\right)$$

This also means that if the direct impact is known,

$$(direct\ [multiplier - 1]) = indirect + induced$$

A.3 Survival rates

Table 12 Survival rates obtained from the Cox model.[40]

Current year	Start year 1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1998	1.00														
1999	0.94	1.00													
2000	0.89	0.95	1.00												
2001	0.86	0.91	0.95	1.00											
2002	0.82	0.88	0.91	0.93	1.00										
2003	0.78	0.85	0.88	0.88	0.93	1.00									
2004	0.78	0.81	0.85	0.85	0.88	0.93	1.00								
2005	0.75	0.81	0.81	0.80	0.85	0.88	0.93	1.00							
2006	0.69	0.79	0.81	0.76	0.80	0.85	0.88	0.98	1.00						
2007	0.64	0.74	0.79	0.76	0.76	0.80	0.85	0.96	0.98	1.00					
2008	0.56	0.70	0.74	0.74	0.76	0.76	0.80	0.95	0.96	0.98	1.00				
2009	0.51	0.63	0.70	0.67	0.74	0.76	0.76	0.94	0.95	0.96	0.98	1.00			
2010	0.51	0.58	0.63	0.62	0.67	0.74	0.76	0.92	0.94	0.95	0.96	0.93	1.00		
2011	0.46	0.58	0.58	0.54	0.62	0.67	0.74	0.92	0.92	0.94	0.95	0.88	0.93	1.00	
2012	0.46	0.53	0.58	0.48	0.54	0.62	0.67	0.91	0.92	0.92	0.94	0.84	0.88	0.93	1.00

A.4 Matching of control and user companies

A.4.1 Propensity score estimation and matching algorithm

We used a logistic model to estimate the PSM scores, using the following variables as predictors: company age, employment, turnover, productivity (defined as turnover per FTE), total equity, total liabilities and operating profit one year *before* the first collaboration took place.

We created an algorithm to select users in each year of its first collaboration and to find a match from the group of non-users (in the same year). This implies that the matching exercise has been performed ten times, once for each possible year of first collaboration within the 2003–2013 period.

There are different approaches to measuring the PSM scores, and we used the "k-nearest neighbour" matching method that identifies one matched non-user for each user based on the proximity of their scores (when k is equal to 1, i.e. only one neighbour is chosen, the one with the closest score).

A.4.2 Common support area

One important step when performing a matching exercise is to check the overlap and the region of common support between treatment and comparison group. i.e. the extent to which the companies in the treatment and control groups actually have

[40] G. Koop and C. J. Ruhm, "Econometric Estimation of Proportional Hazard Models," *Journal of Economics & Business*, Vol. 45, No. 5, 421-30, 1993.

similar scores. The most straightforward way to show this overlap is to present the density distribution of the propensity score in both groups[41], see Figure 42.

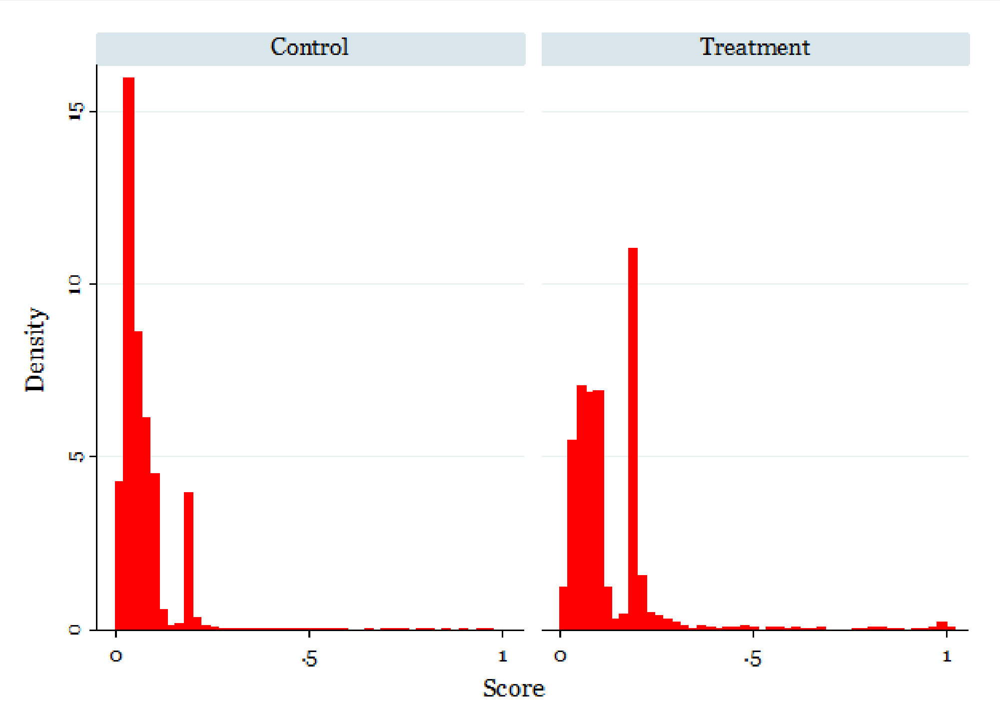

Figure 42 Distribution of scores obtained from the matching estimation.

Once we identified the region of common support, companies outside this region were disregarded (for these companies the treatment effect cannot be estimated). This means that large companies have had to be excluded from the analysis as no match could be found for them. These companies include for example Statoil, Telenor, ExxonMobil Exploration and Production Norway, DNB Bank and other big companies.

A.4.3 Matching quality

Finally, we used a T-test to test whether or not the matching exercise had led to comparable samples after excluding companies that do not fall within the common support area.

Table 13 summarises the statistical analyses that compare the average values of main indicators between the non-user and user groups before and after matching. The p-value corresponds to the two-sample T-test, which is a statistical test used to determine whether two population means are equal. The test that takes into account the average value and standard deviation of the indicators, and the number of observations, to identify whether any observed differences between the two groups are statistically significantly different. A p-value below 5 per cent (0.05, and equivalent to one star) indicates that the difference is statistically significant.

Overall, the table shows that the matching strategy was successful in balancing the groups. The matching exercise resulted in 4,597 companies, 2,657 users and 1,940

[41] Caliendo and Kopeing, "Some Practical Guidance for the Implementation of Propensity Score Matching", IZA DP No. 1588, 2005.

non-users. This implies that in some cases a non-user has been assigned as a good match to more than one user company. This is a large pool that, together with the fact that we had financial data for the period 1998–2013, provided a strong platform for the econometric analysis.

Table 13 T-test results for unmatched and matched groups. Financial data in thousand NOK. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

Year (before) first collaboration	Before matching				After matching			
	Non-users	Users	p-value	Sig.	Non-users	Users	p-value	Sig.
2003								
Age (years)	21	23	0.002	**	24	23	0.300	
No. of employees	34	85	0.000	***	68	90	0.252	
Turnover	69,469	181,718	0.000	***	125,619	192,205	0.024	*
Equity	24,716	132,385	0.000	***	36,888	141,476	0.069	
Profit	1,917	9,808	0.002	**	2,607	10,486	0.041	*
2008								
Age (years)	18	14	0.000	***	16	15	0.582	
No. of employees	34	37	0.779		69	49	0.571	
Turnover	98,483	147,786	0.222		179,664	155,764	0.823	
Equity	41,884	73,355	0.404		254,717	90,286	0.477	
Profit	3,724	15,028	0.103		36,041	14,207	0.501	
2013								
Age (years)	15	10	0.000	***	12	11	0.593	
No. of employees	33	48	0.465		97	66	0.655	
Turnover	101,666	291,474	0.000	***	299,546	289,950	0.962	
Equity	45,766	136,216	0.041	*	324,245	118,102	0.337	
Profit	4,778	30,761	0.000	***	19,677	52,121	0.566	

* p<0.05, ** p<0.01, *** p<0.001

A.5 Econometric estimation

Once the data had been "balanced", we proceeded to perform an econometric analysis using a fixed-effects model. Our basic regressions used the following framework:

$$y_{it} = \alpha + \lambda_t + \delta_i + \beta Z_{it} + \tau X_{it} + \mu_{it}, \quad t = 1998, \ldots 2013,$$

where:

> y_{it}: is the value of the performance indicator for company i, in year t (the dependent variable; e.g. turnover or productivity)
>
> λ_t: represents year dummies ("time fixed effects")
>
> δ_i: represents a vector of individual characteristics that do not change over time (e.g. sector)
>
> X_{it}: represents a vector of individual characteristics that change over time
>
> Z_{it}: is the proxy for participation for company i in year t

In the case of X_{it} we used:

- Size of the company (number of employees)
- Total equity as an indicator of the financial health of a company

Please note that for users, the variable Z_{it} takes the value of 0 up to the year of first collaboration and the value of 1 every year after that. This means that we grouped together the periods "during" and "after" described above. In turn, Z_{it} is always 0 for non-users. The coefficient of this variable (β) is the treatment effect as we measure the effect of going from state 0 (no collaboration in that year) to state 1 (collaboration takes place).

In the analysis, we focused on two performance indicators (y_{it}) (turnover and productivity). The fixed-effects model measures the results in terms of changes over time. For this reason, the model excludes characteristics that do not change over time (δ_i), since the difference between period t to period t+1 on, for instance, sector will be equal to 0. Put differently, the model already accounts for any characteristic of a company that does not change over time (e.g. sector) as they do not play a role in explaining changes in other performance indicators (this is, in fact, why the model is called fixed effects).

A.5.1 Turnover

We ran five models to estimate the effect of the collaboration with the institutes on companies' turnover, following the structure shown in the equation above. All five models use the (logarithm of) turnover as a dependent variable. We used log transformations of income as the data is highly skewed (with many companies concentrated around the lower bound in terms of income). Once the log transformation is applied the data shows a normal distribution, which is a desirable condition for the type of linear regression we use in this exercise.

We accounted for different timeframes in which the impact materialises. The user survey reveals that for most companies (large and SMEs) it takes less than 5 years for the economic benefits of the collaboration with the TI institutes to materialise. Each of the five models uses different lags to account for the time it takes for the effect of the collaboration to materialise. In Model 1 we used one lag and studied the effect of a participation in year t on companies' turnover in year t+1, i.e. if a company started collaborating with a TI institute in 2003, we studied the effect on the performance indicators in 2004. Model 2 we used a two-year lag, in Model 3 a three-year lag etc. This means that in practice we only look at collaboration that took place 2003–2012, since we have (complete) data on performance indicators up to 2013.

The results are shown in Table 14. The table presents the coefficients that capture the relationship between the dependent and independent variables (β *and* τ, in the equation). The standard errors of each coefficient are shown in parenthesis below the coefficients. The numbers shown in the first row of the table (highlighted in grey) are the coefficients of interest (β in the equation). If there is a causal relationship, the coefficient of the indicator that captures participation is positive and statistically significant (denoted by a p-value lower than 0.05). Note that the numbers shown in Figure 35 (in the main report) correspond to the exponential transformation of the coefficients shown in this table.

The models show that collaboration with TI institutes has indeed had a positive effect on companies' turnover. More specifically, the results show that, on average, users have a turnover that is 28 per cent higher in comparison with non-users a year after collaboration took place (where 28%=((exp(0.244)-1)*100) and 0.244 is the coefficient of Table 14). The effect on turnover declines with time, but remains positively and statistically significant up to four years after the collaboration started. In the fifth year the effect becomes statistically insignificant (i.e. equal to zero). This means that, companies that collaborated with a TI institute in 2003 experienced a positive turnover development in the years 2004–2007 compared with non-users. Note that the results should be understood as a comparison of averages. It means that the group of non-users forgo, on average, 28 per cent in year one, 20 per cent year two etc.

F-statistic tests the joint significance of the each model. The p-value equal to zero means that the models are indeed statistically significant. The R-squared for the models is up to 0.134. This means that the model explains 13.4 per cent of the variance of the dependent variable (i.e. turnover). Note that the R-squared tends to be lower in fixed-effect models as the model removes time-invariant factors and the explanatory power provided by them. Hence, an R-squared of 13.4 per cent does not mean that our models do not have a strong enough explanatory power. Table 15 shows the confidence intervals for the (statistically significant) coefficients of the main variable of interest (i.e. collaboration).

Table 14 Estimation of turnover development in the period 1998–2013. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

	Model 1 **coeff./s.e.**	**Model 2** **coeff./s.e.**	**Model 3** **coeff./s.e.**	**Model 4** **coeff./s.e.**	**Model 5** **coeff./s.e.**
Collaboration (=1 if collaboration took place in *t-j*) (where j=1,..,5)	0.244***	0.181***	0.144***	0.095***	-0.019
	(0.017)	(0.020)	(0.021)	(0.022)	(-0.025)
Number of employees	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	0
Total equity	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	0
Time fixed effects (year dummies)	Yes	Yes	Yes	Yes	Yes
Number of observations	46398	46398	46398	46398	46398
F-statistic	89.312	79.412	74.643	71.106	68.281
p-value (F-statistic)	0.000	0.000	0.000	0.000	0.000
R-squared	0.134	0.132	0.131	0.13	0.129

* p<0.05, ** p<0.01, *** p<0.001. Standard errors (s.e.) are shown in parenthesis below the coefficients

Table 15 Confidence intervals for estimations of turnover development.

Collaboration (=1 if collaboration took place in *t-j*) (where j=1,..,4)	**coeff.**	**s.e.**	**[95% confidence interval]**	
Model 1	0.244	0.017	0.211	0.278
Model 2	0.181	0.020	0.143	0.220
Model 3	0.144	0.021	0.103	0.185
Model 4	0.095	0.022	0.052	0.138

The results shown in Table 14 do not take into account differences in collaboration pattern or intensity. To investigate potential differences due to collaboration intensity, we subsequently applied our five models to two sub-samples; the first one only including users that had collaborated in a single year, the second one only including users that had collaborated in multiple years (both sub-samples included their respective matches among non-users).

A.5.2 Productivity

Table 16 shows the results of five regressions all using the (logarithm of) productivity. Just as for turnover, we used five models with five different lags for the independent variable. The coefficients of interest (highlighted in grey in the first row) are positive and statistically significant for models 1, 2 and 3, meaning that collaboration with the institutes have a positive effect on companies' productivity in first three years after the collaboration started. On average, users have a level of productivity that is 5.5 per cent higher than non-users one year after collaboration started (where 5.5%=((exp(0.054)-1)*100) and 0.054 is the coefficient in the first row in the table).

Table 16 Estimation of productivity development in the period 2000–2013. Source: Technopolis analysis of data from RCN's data warehouse, RCN's SkatteFUNN database and Eniro's company database.

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
	coeff./s.e.	**coeff./s.e.**	**coeff./s.e.**	**coeff./s.e.**	**coeff./s.e.**
Collaboration (=1 if collaboration took place in *t-j*) (where j=1,..,5)	0.054***	0.029**	0.037**	0.009	-0.014
	(0.013)	(0.014)	(0.016)	-0.016	-0.016
Number of employees	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	0	0
Total equity	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	0	0
Time fixed effects (year dummies)	Yes	Yes	Yes	Yes	Yes
Number of observations	41067	41067	41067	41067	41067
F-statistic	88.651	88.425	88.314	88.145	88.211
p-value (F-statistic)	0.000	0.000	0.000	0.000	0
R-squared	0.108	0.108	0.108	0.108	0.108

* p<0.05, ** p<0.01, *** p<0.001. Standard errors (s.e.) are shown in parenthesis below the coefficients

F-statistic and p-values show that the models are statistically significant. The R-squared for the models is up to 0.108. This means that the model explains 10.8% of the variance of the dependent variable (i.e. productivity). Table 17 shows the confidence intervals for the (statistically significant) coefficients of the main variable of interest (i.e. collaboration).

Table 17 Confidence intervals for estimations of productivity.

Collaboration (=1 if collaboration took place in *t-j*) (where j=1,..,3)	**coeff.**	**s.e.**	**[95% confidence interval]**	
Model 1	0.054	0.013	0.028	0.079
Model 2	0.029	0.014	0.001	0.057
Model 3	0.037	0.016	0.007	0.068

Appendix B Industry repercussion of higher activity in the R&D/institute sector

Å. Cappelen/J. Ouren
Research Dept.
Statistics Norway

Higher investment in R&D is expected to lead to higher output in the economy due to a direct return on R&D capital accumulated by the R&D investing sectors themselves as well as a social return above what the R&D investors can expect. In order to produce the R&D investment the R&D sector itself has economic effects on other sector of the economy. These effects are the traditional input-output effects. In the most recent international standard of national accounts, R&D expenditures are treated as an investment category just like machinery or buildings. We are therefore able to study the industry effects of higher activity in the firms producing R&D services using standard input output analysis based on details from the national accounts. The R&D sector comprises many types of institutions. In this study we are focusing on what we call "the institute sector" which includes all R&D institutes that are not part of universities. A large part of total R&D is produced within universities. The effects of more R&D spending within universities are not analyses here. Such an analysis would pose some separate issues related to disentangling resources used in education versus R&D that we disregard when focusing only on the institute sector that produced only R&D services and are not much involved in educational activities.

In what follows we analyze what is the effect on output in other industries of an increase in R&D investment of 1 billion NOK (in 2012 prices) produced by the institute sector. We do this within a standard input-output model where all final demand is exogenous and only intermediate inputs are endogenous. In aggregate terms this implies that an increase in R&D investment of 1 billion NOK will increase the sum of GDP and total imports by a similar amount.

Production in the institute sector is a labour intensive process meaning that it takes relatively more labour inputs than material inputs to produce output than if you compare with the economy as a whole. It turns out that of the total increase in final demand of 1 billion NOK in R&D it takes only 88 million NOK of imports to produce all the intermediate inputs needed to produce more R&D. This implies that total GDP increases by 912 million NOK.

Let us now turn to the effects on gross output by industries. Our calculations have been conducted using an industry/commodity input output-model specifying 47 goods and services of which R&D from the institute sector is one. Let X_i denote gross output of commodity "i", D_i is final demand for commodity "i" and M_i is imports of commodity "i". For each commodity there we specify a total commodity balance equation (supply equals demand) and an import equation

$$I_i + X_i = \sum_j a_{ij} X_j + \sum_k d_{ik} D_k$$

$$I_i = \sum_j ma_{ij} a_{ij} X_j + \sum_k md_{ik} d_{ik} D_k$$

In these equations "i" indexes the 47 goods while we specify "k" categories of final demand of which one is R&D investment. The parameters a, d, and m are taken from the final national accounts for 2012. When R&D investment increases by 1 billion NOK, most industries will have to expand their production in order to produce intermediate goods needed to produce more final demand of R&D.

To present some aggregate figures first total gross production has to increase by 1.368 billion NOK in order to produce the increase in R&D. Before going into details about the various industry effects we may now summarize the main aggregate effects in million NOK.

Increase in R&D spending	1 000
Increase in gross production	1 368
Increase in intermediate inputs	456
Increase in GDP	912 (= 1 368 – 456)
Increase in imports	88 (= 1 000 – 912)

The input-output multiplier of R&D investment produced by the institute sector on gross production is thus estimated to 1.368 in 2012.

Which industries are affected by an expansion of the institute sector? Below we show effects on gross production by industry in million NOK somewhat aggregated compared to the most detailed level in the model. The initial increase in output in the institute sector is 1 billion NOK. In order to produce this output the rest of the economy will have increase output in order to deliver intermediates.

Agriculture, forestry and fishing	2
Manufacturing	26
Construction	12
Banking and insurance	16
Electricity production	6
Domestic transports	33
Shipping services	1
Oil and gas	1
Wholesale and retail trade	11
ICT	64
Other business services	126
Rents and property services	40
Government services	10
Institute sector	1 020
Total gross production	1 368

We see that the Institute sector produces intermediate services (consulting services) as well as R&D investments. If we deduct the initial R&D output of 1 billion NOK from gross output the additional expansion of the Institute sector is 20 million NOK. This increase consists of services needed by other industries than the Institute sector in order to increase their output.

It is mostly service industries that are affected by higher output in the Institute sector. In particular the ICT sector and production of other business services increase their output. There are only minor effects on manufacturing industries and it is the sectors producing machinery that are mainly affected. One reason why manufacturing sectors are not much affected has to do with the structure of Norwegian manufacturing. There are few firms producing machinery and equipment for other industries than the shipping and oil industries. So more advanced instruments used by science labs are usually imported and firms delivering services on this equipment would be categorized as belonging to various service industries not manufacturing.

Technopolis Sweden
Faugert & Co Utvärdering AB
Grevgatan 15, 1 tr
114 53 Stockholm
Sweden
T +46 8 55 11 81 11
E tomas.astrom@technopolis-group.com
www.technopolis-group.com