Torbjørn Hægeland and Jarle Møen

The relationship between the Norwegian R&D tax credit scheme and other innovation policy instruments

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Abstract

Torbjørn Hægeland and Jarle Møen

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We first study how participation in the Norwegian R&D tax credit scheme affects the probability of receiving other R&D and innovation subsidies. We find no evidence suggesting that using the R&D tax credit increase the probability of receiving direct R&D subsidies in the future, but we cannot exclude the possibility of an immediate positive effect. At the individual firm level, direct subsidies and the tax credit seem to be complements, while at the innovation system level they seem to be substitutes, as the probability of receiving direct subsidies has fallen after the introduction of the tax credit scheme.

Next, we compare the additionality of the R&D tax credit with direct R&D subsidies. Our preferred estimate suggests that each public krone spent on tax credits for firms investing below the 4 million cap on intramural R&D increases private intramural R&D by 2.68 kroner. This estimate builds on an assumption of zero additionality for firms above the 4 million cap. We find that the additionality of subsidies awarded through the Research Council and Innovation Norway is 2.07 and 1.53 respectively. The additionality of grants awarded by ministries and other public agencies is 0.64, and the additionality of R&D subsidies from the EU is 0.75. We stress the potential for both positive and negative biases in these estimates.

Direct R&D subsidies are intended for projects with low private return and high social return. We find that projects funded through direct grants have essentially zero returns. Although surprisingly low, this is consistent with a high quality grant allocation process. Our estimate for the return to R&D projects financed by tax credits is just slightly below the return to R&D projects financed by own funds. This is to be expected as this type of R&D has a lower marginal price. The estimated returns are 16 % and 19 % respectively. All estimates are likely to be downward biased by measurement errors in the R&D variables. Furthermore, there is large variance in the returns to R&D projects. When estimating the return parameters year by year, they vary considerably around their overall mean.

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Contents

Sammendrag på norsk

Ordninger og tiltak innføres sjelden eller aldri i et vakuum. De kommer gjerne i tillegg til eller i stedet for eksisterende ordninger, og implementeres i en virkelighet hvor andre lover, regelverk og andre generelle virkemidler også påvirker aktørenes tilpasning til og eventuelle effekter av den nye ordningen. Innføringen av SkatteFUNN-ordningen er ikke noe unntak fra dette. I denne rapportent studerer vi hvordan SkatteFUNN-ordningen virker i samspill med andre virkemidler for FoU, med spesiell vekt på hvorvidt innføringen av SkatteFUNN har påvirket sannsynligheten for å få tilgang til eller benytte seg av andre deler av virkemiddelapparatet. I tillegg har vi sett på forskjeller i innsatsaddisjonalitet og avkastning mellom ulike typer virkemidler.

FoU-subsidier gis hovedsakelig som direkte subsidier eller som en eller annen form for skattefradrag. Skatteinsentiver til FoU har blitt mer og mer populært i de siste tiårene, og i flere land er de et viktig supplement til direkte FoU-subsidier. I begge tilfeller er formålet fra myndighetenes side å subsidiere private FoU-prosjekter som blir vurdert som samfunnsøkonomisk lønnsomme, og som ikke ville ha blitt gjennomført uten støtte.

Hvis myndighetene hadde perfekt informasjon, ville direkte subsidier være det foretrukne virkemiddelet. Prosjektene kunne da ha blitt støttet ut fra sin samfunnsøkonomiske lønnsomhet. Et skatteinsentiv ville være mindre effektivt, siden foretak rangerer sine investeringsprosjekter etter bedriftsøkonomisk lønnsomhet. Betydelige subsidier vil bli utbetalt til prosjekter som ville ha blitt gjennomført også uten støtte, og hvor den samfunnsøkonomiske avkastningen ikke nødvendigvis er høy.

Imidlertid er det ikke slik at myndighetene sitter med perfekt informasjon, og det er kostbart å skaffe seg opplysninger om forventet bedrifts- og samfunnsøkonomisk avkastning av enkeltstående FoU-prosjekter. Det er også kostbart for bedrifter å sende inn detaljert prosjektinformasjon til myndighetene. Avhengig av hvordan et skatteinsentiv designes, kan det være en billigere måte å administrere støtten på, både for myndigheter og foretak. En annen viktig fordel er at skatteinsentiver reduserer prisen på FoU på marginen. Dette gir et sterkt teoretisk argument for at et skatteinsentiv vil øke FoU-investeringene. Ved ufullstendig informasjon er det vanskeligere å rangere prosjekter i forhold til samfunnsøkonomisk avkastning. Foretakenes første prioritet må være å få støtte til de prosjektene de uansett ville ha gjennomført. Addisjonaliteten til direkte subsidier vil avhenge av kvaliteten på saksbehandlingen og oppriktigheten til foretakene i søknadsprosessen. Siden direkte subsidier tildeles gjennom en beslutningsprosess og ikke er rettighetsbaserte, kan de også være mer utsatte for lobbyvirksomhet på prosjektnivå.

Mange av foretakene som har mottatt støtte gjennom SkatteFUNN, har ikke tidligere mottatt direkte subsidier til FoU. Gjennom å ha søkt om støtte fra SkatteFUNN, er det mulig at disse foretakene har blitt mer klar over eksistensen av andre virkemidler og muligheten for å søke støtte gjennom dem. Det er imidlertid viktig å påpeke at det er betydelige identifikasjonsproblemer knyttet til å estimere slike effekter, siden det finnes lite i våre data som kan kaste lys over hva foretakene som tidligere ikke har vært kontakt med virkemiddelapparatet ville ha gjort i fravær av SkatteFUNN-ordningen. Vi analyserer problemstillingen fra to vinkler. Vår første tilnærming er å analysere hvordan sannsynlighetene for å motta direkte subsidier til FoU har endret seg etter at SkatteFUNN ble innført. Denne analysen gjøres ved hjelp av data fra FoU-undersøkelsene for 1993-2005. Sannsynligheten for å motta direkte støtte øker med størrelsen på FoU-investeringene, og med størrelsen på tidligere direkte subsidier. Vi finner også at sannsynligheten for å motta direkte subsidier er betydelig lavere i årene etter at SkatteFUNN ble innført. Den estimerte endringen i sannsynlighet er -16,2 prosent. Foretak som mottok støtte gjennom SkatteFUNN hadde imidlertid en 5,4 prosent høyere sannsynlighet for å motta direkte støtte enn andre foretak. En tolkning av disse resultatene er at SkatteFUNN er substitutter på makronivå (generelt lavere sjanse for å få direkte subsidier etter at SkatteFUNN ble innført), mens de er komplementære for individuelle foretak som søker støtte til sine FoU-prosjekter.

I vår andre tilnærming ser vi på det samme spørsmålet ved bruk av data fra prosjekt- og kundedatabasene til Norges forskningsråd og Innovasjon Norge (inkludert forløpere), kombinert med informasjon fra SkatteFUNN-databasen og generell foretaksinformasjon fra Statistisk sentralbyrås strukturstatistikk. Hovedformålet er å se hvorvidt eksistensen av SkatteFUNN ser ut til å ha stimulert foretak til å søke også andre former for støtte. Vi finner at foretak som har søkt Norges forskningsråd eller har mottatt en eller annen form for støtte fra Innovasjon Norge året før, har signifikant større sannsynlighet for å gjøre det samme året etter i perioden etter at SkatteFUNN ble innført. Det kan dermed synes som om SkatteFUNN har gitt noe større persistens i bruken av det øvrige virkemiddelapparatet. Vi finner imidlertid ingen tegn til at foretak som tidligere ikke har søkt Norges forskningsråd eller har mottatt en eller annen form for støtte fra Innovasjon Norge, har noen større sjanse for å gjøre dette etter at SkatteFUNN ble innført.

I tillegg har vi gjort en nærmere analyse av foretakenes kontakt med Norges Forskningsråd og Innovasjon Norge etter at SkatteFUNN ble innført. Denne analysen viser igjen tydelig at de som har hatt kontakt med virkemiddelapparatet før innføringen av SkatteFUNN, også har større sannsynlighet for dette etter at ordningen ble innført. I tillegg er SkatteFUNN-foretak i større grad enn andre i kontakt med virkemiddelapparatet. Dette er ingen overraskelse, siden foretak som driver med FoU vil forsøke ulike støttekilder. Det som er mer verdt å merke seg er at "SkatteFUNN-effekten" ser ut til å være større for foretak som ikke tidligere har vært i kontakt med virkemiddelapparatet. Dette kan være en indikasjon på at SkatteFUNN leder foretak videre inn til andre deler av virkemiddelapparatet. Det kan imidlertid også indikere at andre deler av virkemiddelapparatet oppfordrer til eller krever at søkere også benytter seg av rettighetsbaserte ordninger som SkatteFUNN.

Når vi sammenligner addisjonaliteten av SkatteFUNN-støtte og direkte subsidier, tar vi utgangspunkt i rammeverket som er benyttet Hægeland og Møen (2007). Vi finner at foretak under beløpsgrensen for fradragsberettiget FoU i SkatteFUNN i gjennomsnitt øker sin FoU-investeringer med 2,68 kroner per krone de mottar i støtte gjennom SkatteFUNN. Det er ikke åpenbart hvorvidt dette skyldes selve skattekreditten eller at foretak selekterer seg inn i SkatteFUNN når de uansett ville ha økt sine FoU-investeringer.

Den estimerte addisjonaliteten av direkte subsidier er noe lavere, 1,18 kroner per krone mottatt i støtte. Selv om den estimerte addisjonaliteten for direkte subsidier er lavere enn for SkatteFUNN, er størrelsen på koeffisientene en indikasjon på at slike ordninger også fungerer bra. Man vil forvente at eksternalitetene knyttet til prosjekter som er valgt til å få direkte subsidier er større enn for prosjekter som kvalifiserer til støtte gjennom SkatteFUNN, siden sistnevnte er valgt av foretakene utelukkende på bakgrunn av bedriftsøkonomisk lønnsomhet. I tillegg gjelder addisjonaliteten knyttet til SkatteFUNN bare foretak under beløpsgrensen. Hvis vi splitter direkte subsidier etter finansieringskilde, finner vi at addisjonalitetseffekten er størst for støtte gjennom Norges forskningsråd, og minst for støtte fra EU og departementer.

Både direkte subsidier og SkatteFUNN er ment å stimulere til økte FoU-investeringer, men utvelgelsen av prosjekter er som nevnt fundamentalt forskjellig i de to typene ordninger. Direkte subidier tildeles i prinsippet ut fra samfunnsøkonomiske lønnsomhetskriterier, mens i SkatteFUNN er det foretakenes egne vurderinger som ligger til grunn. Ut fra dette skulle man forvente at den bedriftsøkonomiske avkastningen var høyere for SkatteFUNN-prosjekter. Vi har gjort en sammenlingning av sammenhengen mellom veksten i foretakenes totale faktorpoduktivitet og FoU finansiert henholdsvis gjennom egne midler, gjennom direkte subsidier og gjennom SkatteFUNN. Under relativt strenge forutsetninger kan disse sammenhengene tolkes som bedriftsøkonomiske avkastningsrater. Avkastningsraten vi finner er i tråd med tidligere internasjonale og norske studier. Vårt beste anslag for den privatøkonomiske bruttoavkastningen på FoU er 15 prosent. Vi finner at FoU utført med støtte fra SkatteFUNN har litt lavere avkastning enn egenutført FoU, mens den privatøkonomiske avkastningen av FoU finansiert av direkte subsidier er lavere. Det siste funnet er ikke overraskende, gitt at disse prosjektene selekteres etter andre kriterier.

1. Introduction

Policies to stimulate innovation and economic growth are high on the policy agenda in all OECD-countries. A strong link between investments in research and growth is often taken for granted, and many countries have explicit and ambitious goals regarding the economy's R&D intensity. In Norway, there is a 3 percent target for R&D as a share of GDP.

Setting a goal suggests that there is a role for government intervention, and there are many potential market failures in the market for research and development. In theory, these could lead to overinvestment as well as underinvestment, but based on empirical research there is a fairly broad consensus that a purely competitive market underinvests in R&D.[1]

There are many policy tools available to improve upon the market outcome. First, governments may produce R&D themselves. Second, intellectual property right laws, ensuring that investors are able to capture the rents from innovations, are very important. Third, there are several important links between competition policies and innovation. Fourth, well regulated capital markets are crucial, and there may also be a role for public money in order to secure funding of new ventures. Finally, the government may subsidize R&D investments made by private firms. OECD countries spend large sums on R&D subsidies, and R&D policies receive much attention in the public debate. However, there is no strong consensus regarding the effectiveness of such policies.

R&D subsidies are mainly given as R&D tax credits or through direct grants.[2] Tax incentives have become an increasingly popular policy tool over the last decades, and in several countries it is a very important supplement to direct R&D subsidies. In both cases, the aim of the policy from the point of view of the government is to subsidize private R&D projects that would not be undertaken without a subsidy, and where the social rate of return is above the risk adjusted required rate of return on public investments.

If the government had perfect information, direct subsidies would be the preferred tool, as projects could be given support based on their social rate of return. An R&D tax credit would be less efficient, as firms rank projects according to their private returns. Substantial subsidies will be paid to projects that would be undertaken without a subsidy, and where spillovers to other firms or consumers may be modest. This implies that under a tax credit there is (*i*) a deadweight loss, since some of the subsidies are pure transfers financed by tax revenues, and (*ii*) a non-optimal mix of projects undertaken because firms decide what projects to do themselves. However, public servants do not have perfect information, and acquiring information on private and particularly social returns is costly. Submitting detailed information to public agencies is also costly for firms. Depending on how the tax credit scheme is set up, administering subsidies through R&D tax credits may be cheaper for both government and firms. This is one main advantage of using tax credits for R&D. Another main advantage is that R&D tax credits reduce the price on R&D investments, giving incentives on the margin to increase R&D investments. Hence, there is a strong theoretical case for thinking that the R&D investments will increase.

The ranking of projects according to social return is difficult with imperfect information. Firms' first priority will be to get subsidies for projects they would undertake in any case. The degree of "additionality" from direct grants will depend on the quality of public servants and the honesty of firms. Since R&D subsidies are awarded through a discretionary process, it is also more vulnerable to lobbying, which may be a serious drawback. Furthermore, grants may be more vulnerable to year to year budget constraints and politicians' short term priorities, than more "rights-based" tax credit schemes. Lack of stability in R&D grants is very unfortunate, as firms' R&D investments

[1] See Griliches (2000) for a broad survey and Wieser (2005) for a recent meta-analysis.

[2] See Hall and van Reenen (2000), David, Hall and Toole (2000) and Garcia-Quevedo (2004) for useful surveys. See also Bloom, Griffith and van Reenen (2002) for an authoritative empirical analysis of R&D tax credits.

are strategic and long term decisions with high adjustment costs.

The present report concerns the relationship between the R&D tax credit scheme and other R&D incentives. It is organized as follows: The next section gives a brief overview of some different R&D support measures in Norway, with focus on direct subsidies from the Norwegian Research Council and the R&D tax credit, SkatteFUNN. Section 3 describes the data sources used in the report. In Section 4, we take a closer look at how the R&D tax credit has affected the probability of receiving direct R&D subsidies and other innovation-related support. Section 5 presents a comparative analysis of the additionality effect of direct subsidies and subsidies given as a tax credit. In section 6, we look at the profitability of R&D financed by direct subsidies versus R&D financed by SkatteFUNN. The final section concludes.

2. A brief overview of R&D support in Norway

2.1. Direct R&D subsidies

Traditionally, Norwegian R&D subsidies have mainly been given as direct grants to firms. The main rule has been programs with "matching grants", where firms are supposed to finance 50 percent of the project they apply for. Research by Klette and Møen (1998) suggests that this own risk money is taken from the ordinary R&D budget and hence would have been spent on R&D anyway. However, firms do not seem to reduce their private R&D budget when they receive subsidies. This implies that the "additionality" is around one, i.e. one krone in subsidy makes firms invest one krone more in R&D.

Earlier research based on surveys from the 1970s, 1980s and 1990s is summarised in Klette and Møen (1998). A weighted average suggests that 34 percent of subsidized projects would not be carried out without the subsidy, 48 percent would be scaled down or delayed and 18 percent would be performed in full without a subsidy.

Klette and Møen (1999) and Møen (2004) have evaluated a large Norwegian R&D subsidy program directed towards the IT industry running from 1987 to 1990. Their conclusions are negative. Klette and Møen (1999) use firm level data only. Comparing subsidized and non-subsidized firms within the high tech industries, they find little evidence in favour of the subsidized firms being more successful. Next, looking at these industries relative to aggregate Norwegian manufacturing, their importance did not increase. Finally, comparing the development of the Norwegian IT industry to the IT industry of other OECD countries, the Norwegian industry did not perform particularly well. Klette and Møen concluded that "the IT-programs were largely unsuccessful". The IT-programs seemed, however, well justified according to economic principles, and Klette and Møen related the lack of success largely to governmental failure such as informational problems and institutional inertia in the agencies heading the implementation of the programs. They noted that

> "…information is a serious obstacle … exactly which firms and what activities should be coordinated and in what way? These serious questions are very hard to answer in a rapidly developing field such as information technology and might be particularly hard to solve in a small open economy where a large majority of the innovations take place abroad. We believe that industrial innovation is an activity where coordination problems and 'market failure' often are pervasive, but it is probably also an activity where policy makers and bureaucrats often lack the information needed to improve on the market solution."

They also noted

> "…coordination problems created by complementary innovative activities across different firms seem in many cases to be at least partly resolved by private institutions such as industry associations, privately funded research joint ventures and other cooperative research agreements."

The program period analysed coincided with a severe recession, and also a technology shift from mini-computers to PCs and open standards. This could be exogenous reasons why the program looked like a failure. Claims have been made that the growth of the Norwegian IT-industry in the late 1990s was stimulated by knowledge built up in formerly subsidized firms. In particular, employees of the fallen industry leader, Norsk Data, have been pointed to as key contributors in a new generation of successful firms.[3] In this case, the evaluation by Klette and Møen may have underestimated the effect. Following up on this, Møen (2004) uses matched employer-employee data and trace workers out of the subsidized firms in order to investigate possible spillovers through labour mobility. The analysis shows that scientists and engineers with experience from subsidized IT-firms to a much larger extent than other scientists and engineers in high-tech industries migrated to the rapidly growing IT service industry. They have not

[3] Norsk Data was the last IT company in a series of 'national champions' actively promoted by the Norwegian government.

performed badly, but there is no evidence indicating that these scientists and engineers played a particularly prominent role in the growth process, either. Nor do spin-off firms from the subsidized firms perform particularly well. In fact, they seem to have performed below, rather than above, average. One possible explanation for these discouraging results is that the technology shift in the late 1980s rendered much of the intellectual human capital built up under the programs obsolete.

Another Norwegian evaluation project has been run by professor Arild Hervik at Møre Research. Hervik's group has for many years collected data from so-called user oriented research projects subsidized by the Research Council of Norway. Basically they have been asking firms what they would have done in absence of subsidies, what profits have been realized and what they expect from the subsidized projects in terms of future profits. Hervik, Bræin, Bremnes and Bergem (2006) report that for the years 1997 to 2005, 45 percent of the firms say that their R&D project would have been abandoned without the R&D subsidy. 2 percent say the project would have been carried through without any changes, and 52 percent say the project would have been carried out at a smaller scale or with a delay.

Hervik et al summarize their main results as follows:

> "A principal finding is that a few projects have the potential to generate private sector returns greater than the cost of all projects surveyed. Actual development of competence, new technologies and networking are often more important to the companies than private sector returns in the long run. The projects contribute to the creation of new knowledge; publication of scientific articles, PhD theses and co-operation between universities and research institutes, showing that there are positive external effects. Half of the projects would not have been realized without support and more than 140 projects (with full additionality) started in the period 1995-2002 are reported to achieve a net present value of NOK 2.4 billion. The private sector returns are much higher (NOK 8.4 billion) if we include projects with low additionality. However, without support the projects would be reduced and the potential for external effects would be diminished. The Research Council's project evaluation system (Provis) appears to be a well functioning tool for selecting good quality projects for support." (Our translation).

Obviously, a key identifying assumption behind this research is that the firms are both able and willing to reveal the profitability of the individual projects, and what they would have done in absence of a subsidy.

2.2. The Norwegian R&D tax credit scheme

Introducing an R&D tax credit in Norway was proposed by the Hervik Commission in a green paper for the Ministry of Trade and Industry (NOU 2000:7). The commission was appointed to suggest policy measures aimed at encouraging industry to invest more in R&D. The Norwegian Parliament had earlier in 2000 agreed to make increased R&D investments a national priority, and decided that R&D relative to GDP should at least reach the OECD average by 2005. This illustrates a general point. Generous R&D tax credit schemes are often introduced in countries with low R&D investments by international standards, and where the sentiment is that "something needs to be done".

The Hervik commission suggested using an R&D tax credit as one of several policy tools to stimulate R&D investments. They emphasized that the R&D tax credit they proposed would be administratively simpler and more robust to informational problems than direct subsidies. It was intended to be the main policy tool towards small and medium sized firms (SMEs). In the commission's opinion, the Norwegian Research Council should focus on R&D of strategic importance and spend their resources initiating and evaluating large projects. It also emphasized that a "rights-based" R&D tax credit would give more stable conditions for the business community than direct subsidies. The total subsidy would not be subject to annual budget debates, and the detailed regulations would be embedded in the general tax code. Of course, the specifics of the scheme, such as deduction rates and rules on eligibility etc. could change over time, but it was a widely held view that it would be less vulnerable to "overnight" changes than would direct subsidies.

The tax credit scheme, called SkatteFUNN, was introduced in 2002.[4] SkatteFUNN implies that firms can deduct from tax payable a certain amount of their R&D expenditures. Firms are entitled to the tax credit as long as the R&D-project has been approved by the Research Council of Norway.

Originally, only SMEs were eligible. SME were defined as firms fulfilling two out of the following three criteria: (i) Fewer than 100 employees (ii) an annual turnover less than 80 million NOK – about 10 million Euros (iii) an annual balance sheet total less than 40 million NOK – about 5 million Euros.

Already in 2003 large enterprises were included as well. Large enterprises may deduct from taxes owed 18 percent of expenses related to an approved R&D project. 20 percent deduction is possible if the following conditions for being a "small enterprise" are fulfilled: (i) Fewer than 250 employees, (ii) an annual

[4] The following description borrows at some places directly from OECD (2007, p. 112), Cappelen, Raknerud and Rybalka (2007a, Appendix A) and http://web.skattefunn.no/index.php?kat=English

turnover not exceeding Euro 40 millions or an annual balance sheet total not exceeding Euro 27 millions and (iii) less than 25 per cent of the company is owned by a large enterprise. This distinction between large and small enterprises follows EU/EEA state aid rules. The maximum allowable sum (i.e. the sum from which the tax deduction is calculated) for R&D projects conducted by the enterprise itself, is NOK 4 millions per year (about Euro 500 000). In cases where enterprises collaborate with an approved R&D institution (universities and institutes), the maximum sum is NOK 8 millions. Stimulating cooperation between academia and commerce is considered an important objective of the scheme.

In order to qualify for the scheme, a project must be limited and focused, and it must be aimed at generating new knowledge, information or experience which is presumed to be of use for the enterprise in developing new or improved products, services or manufacturing/processing methods.

There are no specific constraints or extra incentives based on sector or region. Enterprises that are not currently liable for taxation also are eligible. If the tax credit exceeds the tax payable by the firm, the difference is paid to the firm like a negative tax or a grant. If the firm is not in a tax position at all, the whole amount of the credit is paid to the firm as a grant. In practice, this has turned out to be a very important feature, as around three-quarters of the total support given through the scheme is paid out as grants. The payment is made when the tax authorities have completed their tax assessment, and takes place the year after the actual R&D expenses have occurred. The R&D tax credit is thus neutral as between qualifying projects, regions, sectors and the tax position of qualifying firms, but lowers the marginal cost of R&D in small enterprises or low R&D spenders more than in larger ones. For firms that would have spent more on R&D than the maximum amount in the scheme even without the presence of the tax credit, the scheme gives no incentive on the margin to increase R&D investments, although they have a clear incentive to qualify for he scheme and receive the tax deduction

As from the fiscal year 2007, a maximum hourly rate and a maximum number of hours per year for in-house R&D personnel has been introduced. The ceiling for payroll and indirect expenses has been set at NOK 500 per hour (about 60 Euro). Up to 1850 hours per year may be approved per person associated with the project. This has made the scheme slightly less generous.

The Norwegian Parliament has decided to include financial support to unpaid labour in R&D activities in the tax credit scheme as well. This way they hope to reach high tech entrepreneurs that do not draw wages from their firms. The amendment needs to be approved by the EFTA Surveillance Authority (ESA).

3. Data

General information on firms is collected from numerous sources available in Statistics Norway and covers the entire population of Norwegian firms: The structural statistics, the accounts statistics, the tax database, the register of employers and employees and the national education database.

Information related to R&D investments and R&D subsidies are *not* available for the entire population of firms. Prior to the introduction of SkatteFUNN, information on firm level R&D investments are available from the R&D statistics collected by Statistics Norway every second year up to 2001 and annually thereafter. All firms with more than 50 employees are included, and a stratified sample of firms with 10-50 employees[5]. In 2003 a survey was also conducted on firms with less than 10 employees. We use surveys from 1993 onwards.

After the introduction of SkatteFUNN, R&D information has also been collected by the Research Council of Norway among the SkatteFUNN applicants. Some of this information covers the years before the firms apply for support and before the scheme was introduced

There are 17 290 firm year observations in the R&D surveys in the years 1993-2001, i.e. prior to SkatteFUNN. 26 % of these report positive R&D (intramural, extramural or both). After the introduction of SkatteFUNN, in the years 2002-2005, there are 16 464 firm year observations. Out of these 33 % report positive R&D and 20 %, 3249 firm year observations, have applied for an R&D tax credit. The 3249 firm year observations that applied for a tax credit within the R&D surveys constitute only 24 % of the 13 884 firm year R&D tax credit applications in the years 2002 to 2005. Of these 13 884 applications, 11 144, i.e. 80 %, received a tax credit.

Table 3.1 splits firm-year observations that either have received an R&D tax credit or have been included in an R&D survey on employment groups. As one can easily see, firms in the R&D surveys are not a representative sample of the SkatteFUNN firms. The SkattteFUNN data base is dominated by very small firms while the R&D surveys are dominated by medium sized firms.

There are 2598 firm-year observations from 2002 onwards that report positive R&D without having applied for a tax credit[6]. This is 47% of the firms in the R&D surveys with positive R&D. The median R&D for firms with positive R&D that do not apply is only half of the median R&D for firms with positive R&D that do apply. However, average R&D for the two groups is about the same, as some of the firms that do not apply are very large R&D performers. That the group of non-applicants contains both very small and very large R&D performers seems natural.

There are 254 firm-year observations with a positive R&D tax credit that report no R&D in the R&D surveys. This suggests that zeros in the R&D surveys are not entirely reliable. Some firms may claim to do no R&D as a way to minimize time spent on the survey, and there may be errors in the processing of the data.

Out of the 11 144 firm year observations with a positive R&D tax credit, 70 % had all of the tax credit associated with intramural R&D, and 1 % had all of the tax credit associated with extramural R&D. Hence, 29 % had a tax credit associated with both intramural and extramural R&D. 18 % reached the tax credit cap for intramural R&D and 0.5 % reached the cap for total R&D. [7]

[5] In 2003 a special survey was done on firms with less than 10 employees.

[6] Note that large firms in 2002 were not eligible, but adjusting for this does not change the numbers below much.

[7] There are 877 firm-year observations in the R&D surveys that have reached the cap for intramural R&D. 261 of these actually report less than 4 million in intramural R&D, and 194 report less than 3 million. This illustrate that for some firms, the “formula” for calculating R&D costs in the SkatteFUNN application is rather generous. There are no incidences in the R&D surveys of firms reaching the cap for total R&D and reporting less than 8 million in total R&D. Note also that there are 300 firm-year observations in the R&D surveys of firms that get a tax credit and report more than 4 million in intramural R&D without reaching the tax credit cap. 207 of these report more than 5 million in intramural R&D.

Table 3.1. Firm year observations 2002-2005 by data base and number of employees

Included in the SkatteFUNN database	Yes	Yes	Yes		No	No
Included in the R&D survey		No	Yes	Yes	Yes	Yes
Positive R&D					Yes	No
No or missing employees	2158	2158	0	1	0	1
1-9 employees	5786	5700	86	537	62	389
10-19 employees	2065	1371	694	5204	464	4046
20-49 employees	2030	1135	895	3927	496	2536
50-99 employees	952	194	758	2885	548	1579
100-199 employees	415	31	384	2025	462	1179
200 or more employees	478	46	432	1885	556	887
Total	13884	10635	3249	16464	2598	10617

In addition to the information of R&D and R&D support that is available from the R&D surveys and the SkatteFUNN database, we have also utilized information from other sources. From the Norwegian Research Council's project database (PROVIS), we have extracted information on all applications for direct grants in the period 1995-2006. In this study, we use information of whether individual firms have applied or not in a given year. Similarly, we have used information from Innovation Norway's (and predecessors) databases for the years 1995-2006. From this, we have constructed dummy variables indicating whether firms received any kind of support from Innovation Norway in a given year.

See Hægeland et al. (2006), Kjesbu (2006) and Cappelen et al (2007a, Appendix B) for more detailed information about the various sources and variables. Cappelen et al. is written in English, the others in Norwegian.

4. How does the R&D tax credit affect the probability of receiving other R&D and innovation subsidies?

Many of the firms that have received R&D subsidies through SkatteFUNN have not previously received direct R&D subsidies. Having applied for SkatteFUNN, and thereby been in touch with Innovation Norway and the Research Council, it is possible that these firms have become both more motivated to do R&D, and become more aware of the possibility of applying for direct R&D subsidies. A specific point in the evaluation of the SkatteFUNN scheme concerns to what extent SkatteFUNN affects firms' utilisation of other R&D-stimulating measures. Of particular interest is the question of whether SkatteFUNN serves as a low-threshold measure, stimulating new firms to also make use of other measures. In this chapter we investigate this hypothesis by trying to answers questions such as how SkatteFUNN affects the probability of receiving direct subsidies, whether the probability of being in contact with the Norwegian Research Council and Innovation Norway has changed since SkatteFUNN was introduced, and whether being a SkatteFUNN firm affects this probability. Finally, we look at whether previous support from the Research Council and Innovation Norway is associated with the probability of receiving support through SkatteFUNN. We utilize information in the R&D surveys as well as new data sources made available by the Research Council and Innovation Norway. Note, however that we face serious identification problems when trying to answer these simple questions. There is little in our data that shed light on what firms that have not previously been in touch with the public R&D support system would have done if not SkatteFUNN had been introduced.

4.1. An analysis based on information from the R&D surveys

We start out analyzing the probability of receiving direct R&D support using the R&D surveys from 1993 to 2005. Before the introduction of SkatteFUNN in 2002 the surveys were conducted every second year. The sample consists of all firms reporting positive R&D investments. We estimate a probit model for the probability of receiving direct R&D subsidies. The specification is not deducted from a formal economic model, but we control for a number of variables known to be related to R&D and hence possibly to R&D subsidies.

Table 4.1. The probability of receiving direct R&D subsidies

ln(Sales$_t$)	-0.008*
	(0.004)
Sales growth from *t-2* to *t*	0.014*
	(0.008)
ln(Intramural R&D$_t$)	0.043***
	(0.005)
ln(Direct subsidies $_{t-2}$)	0.023***
	(0.002)
Dummy for post SkatteFUNN year[1]	-0.162***
	(0.016)
Dummy for receiving an R&D tax credit at *t*[1]	0.054**
	(0.021)
Dummy for receiving an R&D tax credit at *t-1*[1]	-0.19
	(0.16)
Pseudo R-sq	0.165
No. of obs.	4041

The estimation method is probit and the coefficients represent changes in the probability of receiving direct R&D subsidies for a one unit change in the explanatory variables measured at their means. Industry dummies are included but not reported.

[1] Marginals for discrete change of dummy variable from 0 to 1.

* Significant at the 10 percent level** Significant at the 5 percent level*** Significant at the 1 percent level.

The results are reported in Table 4.1. First, we may note that the probability of receiving direct support increases with the size of the R&D investments, and with the size of direct subsidies received in the previous observation period. It also increases with sales growth, but decreases with size.

Next, we see that the probability of receiving support is significantly lower – both in statistical and economic terms – in the years after SkatteFUNN was introduced. The estimated effect is -16.2 percent. Firms that receive support from SkatteFUNN, however, have a 5.4 percent higher probability of receiving direct support than firms not receiving support from SkatteFUNN. One interpretation of these is that SkatteFUNN and direct subsidies has been substitutes at the policy level while they are complements for individual firms seeking public finance for their R&D investments. The former is hardly surprising, given that the funding for direct R&D subsidies declined somewhat over the period when SkatteFUNN was introduced. The latter is more interesting, it indicates that the two measures to some extent cater to the same firms.

Whether the estimated immediate effect of SkatteFUNN is causal, in the sense that the SkatteFUNN application process leads the firms to seek and receive direct subsidies, or whether it is a result of selection, in the sense that eligible firms self-select into both schemes simultaneously cannot be determined econometrically. What we can say is that if there is a casual effect it is immediate. We see from the "dummy for receiving an R&D tax credit at *t*-1" that receiving SkatteFUNN one year does not increase the probability of receiving direct support the year after. Note, however, that many SkatteFUNN firms have never been included in the R&D surveys, and it is not obvious that the firms in the R&D surveys are representative for the population of SkatteFUNN firms. In chapter 4.2 we perform an analysis on data sets that include all recipients of direct subsidies.

4.2. An analysis based on data from the Research Council and Innovation Norway

In this subsection, we look closer into whether the probability of being in contact with the Norwegian Research Council and Innovation Norway has changed since SkatteFUNN was introduced, and whether being a SkatteFUNN firm affects this probability. Finally, we look at whether previous support from the Research Council and Innovation Norway is associated with the probability of receiving support through SkatteFUNN

Data from the project databases from the Norwegian Research Council and Innovation Norway and its predecessors. The Norwegian Research Council project database (PROVIS) contains information on all the applications to the Research Council from 1995 to. From Innovation Norway and its predecessors, we have information on all firms that had received support of any kind since 1993. We combine these with information from the structural statistics and the SkatteFUNN database. This dataset does not have the limitations with respect to not including small firms as the dataset based on the R&D surveys, but it lacks information on R&D investments. In addition, the quality of the firm identifiers appears to vary somewhat across data sources, so there is some sample attrition due to incomplete matching of data sources.

If SkatteFUNN had a large effect on firms' propensity to seek other kinds of support, we should expect to see a shift in this propensity at the time of the introduction of the scheme. We therefore investigate the probability of submitting an application to the Research Council and/or receiving support from Innovation Norway, and how it has changed over time, conditional on firm characteristics. Since the decision process of contacting these agencies may be quite different for first-time and experienced applicants, we perform the analysis for two different samples. The first sample consists of those who did not submit an application the previous year, while the second sample is those who did. Table 4.2 shows the estimated effects on probability, while table 4.3 presents the corresponding probit estimates. Year 2000 is the reference year. We see that there is a tendency of a higher persistence among previous applicants after the introduction of SkatteFUNN. Those who applied to the Research Council or received support from Innovation Norway one year, were more likely to do sothe next year after the introduction of SkatteFUNN. For non-applicants, the probability of applying the next year is very low, and there is no tendency that the probability increased after the introduction of SkatteFUNN. Doing the analysis separately for the Norwegian Research Council and Innovation Norway (not reported) give very similar results. There are no clear signs of a positive shift in the "recruitment" of new firms into other support measures after the introduction of SkatteFUNN

Table 4.2. The probability of submitting application to the Norwegian Research Council and/or receiving support from Innovation Norway. Reference is year 2000. Probit marginal effects

	Did not apply in t-1	Did apply in t-1
Year 2001	0.009	-0.000***
	(0.017)	(0.000)
Year 2002	-0.040**	-0.001***
	(0.017)	(0.000)
Year 2003	0.043**	-0.001***
	(0.018)	(0.000)
Year 2004	0.063***	0.000
	(0.018)	(0.000)
Log (sales)	-0.012***	0.000***
	(0.004)	(0.000)
Log (employment)	0.062***	0.002***
	(0.006)	(0.000)
Observations	6848	838135

The estimation method is probit and the coefficients represent changes in probability for a one unit change in the explanatory variable measured at their means. Industry and county dummies are included,but not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4.3. The probability of submitting application to the Norwegian Research Council and/or receiving support from Innovation Norway. Reference is year 2000. Probit coefficients

	Did apply in t-1	Did not apply in t-1
Year 2001	0.026	-0.046**
	(0.049)	(0.018)
Year 2002	-0.120**	-0.106***
	(0.051)	(0.018)
Year 2003	0.124**	-0.100***
	(0.050)	(0.018)
Year 2004	0.181***	0.011
	(0.051)	(0.019)
Log (sales)	-0.036***	0.023***
	(0.013)	(0.005)
Log (employment)	0.181***	0.210***
	(0.018)	(0.007)
Constant	-0.650***	-2.989***
	(0.090)	(0.033)
Observations	6848	838135

The estimation method is probit. Industry and county dummies are included, but not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%

Even if there is no increased tendency of new firms being in contact with the Norwegian Research Council and Innovation Norway, it may still be the case that SkatteFUNN firms to a greater extent than other firms seek contact with other support agencies. In table 4.4 we report the results of a probit analysis of the probability of contact with the Norwegian Research Council (NRC) and/or Innovation Norway (IN) after the introduction of SkatteFUNN. We see that those who had contact with IN and NRC some time prior to SkatteFUNN are more likely to have had such contact also after the introduction of SkatteFUNN. In addition, being a SkatteFUNN firm increases the probablility of such contact. This is hardly surprising, since there is some persistence in R&D and innovation activities, and firms that seek support for their R&D may tend to try multiple sources, and are even encouraged to do so by the different agencies. What is more noteworthy, is that that the "effect" of SkatteFUNN seems to be larger for the firms with no prior contact with IN and/or NRC. This may be an indication of SkatteFUNN being a "low-threshold measure", but it may also just reflect that for firms with previous contact with IN or NRC the possible extra effect of SkatteFUNN is already exhausted.

The analysis presented in table 4.5 confirms a plausible presumption: Having been in contact with NRC and/or IN prior to SkatteFUNN increases the probability of applying for support through SkatteFUNN.

Table 4.4. The probability of submitting application to the Norwegian Research Council and/or receiving support from Innovation Norway after the launching of SkatteFUNN. Marginal effects

	IN+NRC	IN	NRC
Contact with IN+NRC prior to SF	0.132***		
	(0.006)		
SkatteFUNN firm	0.017***	0.012***	0.000*
	(0.002)	(0.002)	(0.000)
SkatteFUNN firm*no contact with IN+NRC prior to SF	0.027***		
	(0.004)		
Contact with IN prior to SF		0.122***	
		(0.006)	
SkatteFUNN firm*no contact with IN prior to SF		0.028***	
		(0.004)	
Contact with NRC prior to SF			0.218***
			(0.022)
SkatteFUNN firm*no contact with NRC prior to SF			0.015***
			(0.004)
Log (sales)	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Log (employmnent)	0.001***	0.001***	0.000***
	(0.000)	(0.000)	(0.000)
Observations	220508	220508	220508

Standard errors in parentheses .The estimation method is probit and the coefficients represent changes in probability for a one unit change in the explanatory variable measured at their means. Sales and employment are measured in 2003. Industryand county dummies are included,but not reported.

•significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4.5. The probability ofreceiving support from SkatteFUNN. Marginal effects

Contact with NRC prior to SF	0.078***
	(0.008)
Contact with IN prior to SF	0.102***
	(0.004)
Log (sales)	0.002***
	(0.000)
Log (employment)	0.006***
	(0.000)
Observations	220508

Standard errors in parentheses .The estimation method is probit and the coefficients represent changes in probability for a one unit change in the explanatory variable measured at their means. Sales and employment are measured in 2003. Industryand county dummies are included,but not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%

5. The additionality of direct R&D subsidies vs SkatteFUNN

There is a large international literature on the question of “additionality” in direct R&D subsidies. Garcia-Quevedo (2004) does a meta-analysis of 39 studies reporting altogether 74 different results, and concludes that “The econometric evidence … is ambiguous”. One might perhaps argue that the question cannot be answered once and for all. Whether subsidies are a substitute for or a complement to privately financed R&D depends on features of the program analyzed. Furthermore, there are several econometric problems related to such analyses, see David, Hall and Toole (2000) and Jaffe (2002) for surveys. Lichtenberg (1984) points out that firm fixed effects are likely to be correlated with subsidies, and Kauko (1996) adds to this that contemporaneous shocks also could cause a bias. The fixed effect will pick up such things as R&D experience, networks and experience with the application process, technological opportunities in the firm’s product group etc. The contemporaneous effect could pick up that that firms that get a good idea both will apply for a subsidy and perform more R&D than previously even without a subsidy. Wallsten (2000) explains the basic problem in one sentence: “Regressing some measure of innovation on the subsidy can establish a correlation between grants and R&D, but it cannot determine whether grants increase firm R&D or whether firms that do more R&D receive more grants”.

Controlling for contemporaneous shocks that may be correlated with applying and receiving a subsidy, demands some sort of exogenous variation in subsidies that is very hard to find. It is beyond the scope of this report to fully solve this identification problem. We will control for firm fixed effects, but the regressions below should be thought of as descriptive regressions where the estimated effects are a combination of the causal effect of the subsidies and the potential contemporaneous selection effects explained above. We believe these selection effects are mostly positive although in theory they could also be negative.[8] Note, however, that there are also a potentially important bias working in the opposite direction. R&D is difficult to measure, and some firms may not put in enough effort in providing good figures when answering the R&D surveys. Errors in our explanatory variables will bias the estimated coefficients towards zero.

When estimating the additionality of direct R&D subsidies, the most common functional form is linear, i.e. subsidies in kroner are regressed on R&D in kroner. With neither crowding out nor crowding in, each krone in subsidy should increase R&D by one krone. With a successful matching grant regime, each krone subsidy should give two kroner in additional private sector R&D. With full crowding out, subsidies will not affect R&D investment and hence the estimated coefficient will be zero. Full crowding out implies that R&D financed by own funds is reduced krone by krone as firms receive subsidies. They then use subsidies to finance R&D that they otherwise would have financed themselves.

Although a linear specification seems most appropriate, some studies also use a log-linear functional form (log-log). The coefficients can then be interpreted as elasticities, i.e. a one percent increase in subsidies give rise to a constant percentage rise in R&D. There is no theoretical justification for this, but it can be thought of as a robustness exercise. It will reduce potential heteroskedasticity and the influence of potential outliers.

We want to compare the additionality of subsidies given as direct grants with the R&D tax credit introduced in 2002. The choice of functional form then becomes more complicated, and to the best of our knowledge, there are no studies in the international literature that attempts to make such a comparison.

The preferred theoretical framework for estimating the effect of a tax credit is a demand equation with the tax credit generating variation in the price of R&D.In a companion report, Hægeland and Møen (2007), we give a thorough discussion of different approaches and identification problems in light of the design of the Norwegian tax credit scheme. A loglinear functional

[8] This was proposed by Klette and Møen (1999) when analysing Norsk Data and the large IT-programs in the 1980 and 1990s.

form is usually recommended (Hall and van Reenen, 2000). However, theory does not predict a certain relationship between the size of the tax credit – whether in kroner or log of kroner – and R&D. A firm that is induced by the tax credit to do a small SkatteFUNN project and receive 20 percent of this as a tax credit, will have an additionality of 5, a firm that does R&D well above the 4 million cap will receive 720 000 or 800 000 in tax credit, but has no additionality at all in absence of liquidity constraints or internal political processes related to the investment budget.[9] Nonetheless, by including the size of the tax credit as a regressor alongside direct subsidies, we can as a descriptive exercise estimate the average additionality for the firms in the sample. Once again, we should stress that this is not a causal effect. It will be a mix of the average true additionality and potential selection effects.

Since firms that would invest above the cap in absence of SkatteFUNN do not have a direct incentive to increase their R&D investments, we follow Hægeland and Møen (2007) and interact SkatteFUNN with a dummy for whether or not the firms' mean investment level prior to SkatteFUNN was below the cap. We use the firms' average investment level prior to SkatteFUNN to proxy whether firms would invest above or below the cap after SkatteFUNN was introduced. The difference between firms above and below the cap is likely to be less biased than the absolute increase for each of the groups. Implicitly, this means that we use firms above the cap to tell us what the firms below the cap would have invested in absence of the tax credit. To the extent that firms above the cap also have some additionality, this causes a downward bias. Moreover, there is no way we can know which firms would be above or below the cap in absence of SkatteFUNN. Using a proxy based on historical R&D investments causes some misclassifications and this will also lead to a downward bias as we contaminate the treatment and the control groups. We refer to Hægeland and Møen (2007) for a more thorough discussion.

5.1. Average additionality for direct subsidies

Since theory cannot guide us with respect to the choice of functional form, we will estimate both linear and log-linear relations. Our main estimates can be found in table 5.1. The analysis is restricted to intramural R&D, as information on subsidies for extramural R&D has not been collected systematically in the R&D surveys.

Taken at face value, the regression on the full sample in column (1) tells us that firms below the cap on average increase their R&D by 2.68 kroner per krone in tax credit received when entering SkatteFUNN. As pointed out above, to what extent this is due to the tax credit or to the firms self selecting into SkatteFUNN when planning to increase their R&D investments cannot be determined. To the extent that the selection process is the same for firms above and below the cap, this is accounted for in the 1.35 additionality estimate for firms above the cap. However, as discussed in Hægeland and Møen (2007), the assumption of equal selection process above and below the cap is not obvious. It may be the case that firms doing little R&D but planning to increase R&D investment are more likely to self-select into the scheme than firms doing a lot of R&D. This will contribute to bias our additionality estimates upward. On the other hand, if not all of the 1.35 additionality estimate for firms above the cap is driven by selection and unobserved macroeconomic conditions, the true additionality for firms below the cap will be larger as the total increase in R&D for this group is the sum of the two coefficients. Moreover, various measurement problems pointed out above also suggest that 1.35 is more likely to be a conservative than a generous estimate.

Table 5.1. The effect of the tax credit and direct subsidies on R&D investments

	(1) All firms	(2) All firms	(3) SME	(4) Large firms
Tax credit	1.35	1.07	0.49	1.77
	(0.89)	(0.86)	(1.16)	(1.29)
Tax credit * Below 4 mill	2.68***	3.04***	3.22**	2.69**
	(0.96)	(0.93)	(1.32)	(1.33)
Direct subsidies	1.18***	1.05***	0.72***	1.66***
	(0.21)	(0.21)	(0.11)	(0.35)
Direct subsidies * Below 4 mill		0.58**	0.53**	0.27
		(0.29)	(0.22)	(0.43)
ln(Sales)	788.99***	1700.05***	1876.32***	1584.92***
	(170.36)	(477.05)	(602.53)	(590.66)
ln(Sales) * Below 4 mill		-1356.70***	-1583.01***	-1236.55**
		(482.42)	(612.53)	(598.37)
Adj.R-sq (within)	0.09	0.10	0.14	0.10
No. of obs.	8233	8233	3803	4430

The dependent variable is intramural R&D. All variables are measured in real NOK. All regressions include firm fixed effects. The sample consist of firms that have reported positive R&D in at least one year before 2002 and that has never reported R&D above 40 mill. Firms are included in the sample up until the first year they receive an R&D tax credit. Time dummies are included, but not reported. Huber-White robust standard errors allowing for clustering of errors by firms are reported in parenthesis. "Below 4 mill" is a dummy for firms' mean level of real intramural R&D investments prior to the introduction of SkatteFUNN in 2002 being below the 4 million cap.

*** Significant at the 1 % level** Significant at the 5 % level* Significant at the 10 % level

[9] "Well above" to account for the possibility that firms with R&D just above the cap would have been below the cap in absence of the tax credit.

The estimated average association between direct R&D subsidies and firms' R&D investments are somewhat smaller. Our overall estimate is 1.18. In column (2)-(4) we allow for heterogeneity between small and large R&D performers as measured by being above or below the 4 million tax credit cap. We see from column (2) that firms that on average invested more than 4 million in R&D prior to 2002 do 1.05 krone more R&D than "usual" in years when they receive one krone more in direct subsidy than "usual". ("Usual" meaning the firm specific average over time that is the base line in a fixed effects regression.) Firms that used to invest less than 4 million have higher additionality, 1.05+0.58=1.63. Potential selection suggests that this estimate may be too high, while possible measurement error in the direct subsidy variable may cause a downward bias. However, the estimated effect is so large and significant that it seems reasonable to conclude that direct subsidies have a fairly high degree of additionality for small R&D performers (firms below 4 million prior to 2002). The degree of additionality for larger R&D performers (above 4 million) also seems acceptable, since the point estimate is slightly above 1. An additionality of one implies that the subsidy is spent on R&D krone by krone.

Even if the estimated additionality of direct subsidies is smaller than the estimated additionality of the tax credit, the estimated coefficients suggests that the direct subsidy regime works well. One would expect that the average externality associated with projects chosen by grant awarding public agencies are larger than the average externality associated with project qualifying for the tax credit. The latter projects are chosen by the firms solely based on expected private return. Recall also that the estimated additionality for the tax credit is for firms below the 4 million cap. Hence the average additionality for all firms will be substantially smaller, as firms above the cap have little incentive to increase their R&D in response to the tax credit.

In column (3) and (4) the firms in the sample are split in two groups according to size. We do this primarily to explore whether small and medium-sized firms have a different degree of additionality than large firms, but the exercise may also be considered a robustness check. Small and medium sized firms (enterprises) – SMEs – are defined according to the 2002 SkatteFUNN rules, see section 2.2.

To take the robustness perspective first, we see that significant and positive additionality can be found in both subsamples and for both types of subsidies. Looking more in detail, we see that the additionality associated with the tax credit is somewhat larger for SMEs (3.22) than for larger firms (2.69). This is reasonable, as small firms are more likely to be liquidity constrained and the subsidy matters more to the profitability of small firms than large firms. With respect to the additionality of direct R&D subsidies we see that the difference between small and large R&D performers found in column (2) is driven by the SME group. Small R&D intensive firms exibit less additionality (0.72) than other small firms(0.72+0.53=1.25) and large firms. Given fairly large adjustment costs, it may be rational for small firms with R&D as a main focus not to scale their R&D investments up and down based on annual public grants quite as much as less R&D intensive firms. It is still possible that reduced subsidies to this group of firms would have long term effects on their level of R&D investments. In this report we restrict ourselves to analyse short term additionality. Long run effects are far more difficult to assess.

In table 5.2 we check the robustness of our findings above by using a log-log functional form. The coefficients are then elasticities, i.e. the percentage change in R&D associated with a one percentage change in subsidies and tax credits. Taking logs will also tend to reduce the influence of the largest R&D performers in the sample. Consistent with this, we see that the main difference from table 5.1 is that the estimated difference between small and large R&D performers is somewhat smaller in relative terms – although still highly significant. We also see that the difference between SMEs and large firms is much less noticeable. Finally, this analysis suggests that the additionality effects of direct subsidies and tax credits are of similar magnitude.

Table 5.2. The effect of the tax credit and direct subsidies on R&D investments – loglinear specification

	(1) All firms	(2) All firms	(3) SME	(4) Large firms
ln(Tax credit)	0.190***	0.162***	0.198***	0.156***
	(0.026)	(0.027)	(0.037)	(0.040)
ln(Tax credit) * Below 4 mill	0.298***	0.329***	0.296***	0.368***
	(0.029)	(0.030)	(0.041)	(0.045)
ln(Direct subsidies)	0.360***	0.222***	0.149***	0.267***
	(0.022)	(0.033)	(0.046)	(0.044)
ln(Direct subsidies) * Below 4 mill		0.230***	0.277***	0.203***
		(0.042)	(0.059)	(0.058)
ln(Sales)	0.329***	0.443**	0.661**	0.348
	(0.114)	(0.204)	(0.261)	(0.253)
ln(Sales) * Below 4 mill		-0.125	-0.195	-0.096
		(0.244)	(0.322)	(0.302)
Adj.R-sq (within)	0.13	0.13	0.17	0.12
No. of obs.	8233	8233	3803	4430

The dependent variable is log of intramural R&D in real NOK. All regressions include firm fixed effects. The sample consist of firms that have reported positive R&D in at least one year before 2002 and that has never reported R&D above 40 mill. Firms are included in the sample up until the first year they receive an R&D tax credit. Time dummies are included, but not reported. Huber-White robust standard errors allowing for clustering of errors by firms are reported in parenthesis. "Below 4 mill" is a dummy for firms' mean level of real intramural R&D investments prior to the introduction of SkatteFUNN in 2002 being below the cap, 4 million NOK.

*** Significant at the 1 % level** Significant at the 5 % level* Significant at the 10 % level

5.2. Additionality for direct subsidies by source

The variable direct subsidies comprises subsidies from several different sources. In table 5.3 and 5.4 we include subsidies from the various sources as separate variables, hence asking whether the degree of additionality vary between different types of public funds. This is to be expected, as the required own funding in projects vary systematically between the various agencies that give support to private R&D.

From Table 5.3, we see that funding from the Research Council have the highest degree of additionality, with a coefficient around 2. The estimated effect is slightly larger for large than for small R&D performers, and slightly larger for large firms than for SMEs. These differences are not significant, and overall, the results are quite consistent with a successful matching grant regime. A competing explanation, however,could be that firms turn to the Research Council in years when they have particularly good projects and that they would increase their R&D even without support.

The estimated additionality for support from Innovation Norway is 1.53. Here, large firms seem to have higher additionality than SMEs. This is slightly surpriseing as one would think that increasing the R&D intensity of SMEs is a particularly important target for Innovation Norway.

R&D subsidies awarded through ministries (including support from directorates, counties, municipalities and other unspecified public agencies) have lower additionality than R&D grants from other sources. The overall estimate is 0.64. The additionality seem to vary quite a bit between different types of firms, but the precision of the estimates are fairly low. It seems that small R&D performers have higher additionality than large R&D performers, and the additionality for large firms with R&D investments above 4 millions seems close to zero.

R&D support from ministries and other public agencies outside the Research Council and Innovation Norway is likely to be contract research. Hence there is no a priori reason to expect a high degree of additionality here. Still, coefficients significantly below 1 may at first glance seem suspicious. This implies that the firms' R&D budgets increase with less than what they receive. On second thought, however, this need not be illegitimate in a contract research setting. It may reflect that the firms do not have capacity to do a large R&D contract on top of what they otherwise would have done, and that the contracts therefore crowd out other projects. The ministries may still get what they pay for.

Table 5.3. The effect of the tax credit and direct subsidies on R&D investments, by source

	(1) All firms	(2) All firms	(3) SME	(4) Large firms
Tax credit	1.46*	1.24	0.54	1.90
	(0.85)	(0.82)	(1.09)	(1.27)
Tax credit * Below 4 mill	2.55***	2.79***	3.08**	2.55*
	(0.93)	(0.90)	(1.26)	(1.31)
Direct subsidies from				
The Research Council	2.07***	2.04***	1.69***	2.18***
	(0.34)	(0.42)	(0.35)	(0.60)
The Research Council * Below 4 mill		-0.21	-0.12	-0.14
		(0.46)	(0.45)	(0.66)
Innovation Norway	1.53***	1.38***	0.52**	1.96***
	(0.35)	(0.49)	(0.26)	(0.65)
Innovation Norway * Below 4 mill		0.28	0.48	0.04
		(0.60)	(0.48)	(0.76)
Ministries	0.64***	0.52	0.49	0.01
	(0.24)	(0.32)	(0.37)	(0.55)
Ministries * Below 4 mill		0.77**	0.77**	1.26*
		(0.36)	(0.37)	(0.72)
EU	0.75***	0.67***	0.65***	0.95*
	(0.12)	(0.11)	(0.11)	(0.57)
EU * Below 4 mill		1.56*	1.84	1.05
		(0.92)	(1.21)	(1.42)
ln(Sales)	760.91***	1608.70***	1751.88***	1531.10***
	(170.47)	(473.81)	(620.06)	(587.36)
ln(Sales) * Below 4 mill		-1271.24***	-1450.51**	-1186.28**
		(479.42)	(631.01)	(594.96)
Adj.R-sq (within)	0.10	0.11	0.15	0.10
No. of obs.	8104	8104	3724	4380

The dependent variable is intramural R&D. All variables are measured in real NOK. All regressions include firm fixed effects. The sample consist of firms that have reported positive R&D in at least one year before 2002 and that has never reported R&D above 40 mill. Firms are included in the sample up until the first year they receive an R&D tax credit. Time dummies are included, but not reported. Huber-White robust standard errors allowing for clustering of errors by firms are reported in parenthesis. "Below 4 mill" is a dummy for firms' mean level of real intramural R&D investments prior to the introduction of SkatteFUNN in 2002 being below the cap, 4 million NOK. *** Significant at the 1 % level** Significant at the 5 % level* Significant at the 10 % level

Table 5.4. The effect of the tax credit and direct subsidies on R&D investments, by source – loglinear specification

	(1) All firms	(2) All firms	(3) SME	(4) Large firms
ln(Tax credit)	0.181***	0.160***	0.193***	0.156***
	(0.026)	(0.026)	(0.037)	(0.039)
ln(Tax credit) * Below 4 mill	0.314***	0.340***	0.304***	0.381***
	(0.029)	(0.030)	(0.042)	(0.045)
ln(Direct subsidies) from				
The Research Council	0.296***	0.178***	0.081*	0.231***
	(0.027)	(0.036)	(0.045)	(0.046)
The Research Council * Below 4 mill		0.225***	0.287***	0.203***
		(0.051)	(0.069)	(0.067)
Innovation Norway	0.296***	0.186***	0.163***	0.222***
	(0.030)	(0.049)	(0.054)	(0.073)
Innovation Norway * Below 4 mill		0.177***	0.170**	0.159*
		(0.062)	(0.074)	(0.092)
Ministries	0.210***	0.123***	0.092*	0.158***
	(0.041)	(0.042)	(0.055)	(0.059)
Ministries * Below 4 mill		0.168**	0.177	0.159
		(0.077)	(0.109)	(0.103)
EU	0.066	0.034	0.089	-0.021
	(0.047)	(0.043)	(0.061)	(0.059)
EU * Below 4 mill		0.138	0.121	0.141
		(0.113)	(0.158)	(0.162)
ln(Sales)	0.346***	0.447**	0.613**	0.344
	(0.116)	(0.210)	(0.274)	(0.261)
ln(Sales) * Below 4 mill		-0.103	-0.068	-0.090
		(0.250)	(0.337)	(0.309)
Adj.R-sq (within)	0.12	0.13	0.17	0.11
No. of obs.	8104	8104	3724	4380

The dependent variable is log of intramural R&D in real NOK. All regressions include firm fixed effects. The sample consist of firms that have reported positive R&D in at least one year before 2002 and that has never reported R&D above 40 mill. Firms are included in the sample up until the first year they receive an R&D tax credit. Time dummies are included, but not reported. Huber-White robust standard errors allowing for clustering of errors by firms are reported in parenthesis. "Below 4 mill" is a dummy for firms' mean level of real intramural R&D investments prior to the introduction of SkatteFUNN in 2002 being below the cap, 4 million NOK.

*** Significant at the 1 % level** Significant at the 5 % level* Significant at the 10 % level

The final type of R&D support specified is support awarded through the EU system. The overall estimate is fairly modest, 0.75, but this seems to be driven mostly by large R&D performers. Small R&D performers have a high degree of additionality, 0.67+1.56=2.23. However, there could be a substantial selection bias involved in this estimate, as it is likely to be very difficult for small R&D performers to succeed in the EU system.

In table 5.4 we redo the above analysis using a log-log functional form. This specification suggests that small R&D performers have a higher degree of additionality, as measured in elasticities than large R&D performers for all types of direct subsidies.

6. The profitability of R&D financed by direct subsidies vs R&D financed by SkatteFUNN

Both direct grants and tax credits are policy tools to induce private R&D projects that would not be undertaken without a subsidy. As we have discussed in the introduction, they differ with respect to how projects are selected. Direct subsidy programs have public agencies involved in choosing the R&D projects that receive financing. Their aim is to select projects with large externalities that would not have been undertaken without the subsidy, i.e. projects that have a low private return. A tax credit, on the other hand has no such selection process attached to it, hence firms will rank projects according to their private return. Much of the subsidy will then be paid to inframarginal projects that would be undertaken even without a subsidy, i.e. projects with a high private return. The mechanism utilized by the government is simply to induce more R&D by lowering the marginal price. If the different subsidy schemes work according to “theory”, projects should differ with respect to private returns depending on their source of financing. In this section, we aim to estimate the private return to R&D and distinguish between R&D that firms finance by own funds, R&D financed by direct grants, and R&D financed by tax credits.

6.2. A standard framework for estimating returns to R&D

We build on the R&D capital model laid out e.g. in Griliches (1973, 1979 and 2000). Variations of this framework are widely used in studies of the return to R&D, see Mairesse and Sassenou (1991) and Wieser (2005) for good reviews of the methodological and empirical literature. [10]

We assume that firms’ technology can be described by an extended Cobb-Douglas production function with constant returns to scale in the conventional inputs, labour, material and physical capital.

$$(1)\quad Q_{it} = AL_{it}^{\beta} M_{it}^{\gamma} C_{it-1}^{1-\beta-\gamma} K_{it-1}^{\varphi} e^{\alpha_i \varepsilon_{it}}$$

where Q_{it} is output measured by total operational income (sales)
L_{it} is labour measured by total man hours[11]
M_{it} is materials
C_{it} is services from physical capital

K_{it} is knowledge capital (R&D capital), the variable of key interest in our analysis.

β, γ and φ are elasticities, and $\alpha_i \varepsilon_{it}$ is a random disturbance term. α_i could e.g. account for unobserved variation in the quality of labour between firms.

Taking logs of (1) we get

$$(2)\quad \begin{aligned} \ln Q_{it} &= \ln A + \beta \ln L_{it} + \gamma \ln M_{it} + \\ &(1-\beta-\gamma)\ln C_{it-1} \\ &+ \varphi \ln K_{it-1} + \alpha_i + \varepsilon_{it} \end{aligned}$$

Taking first differences of (2), we get

$$(3)\quad \begin{aligned} q_{it} &= a + \beta l_{it} + \gamma m_{it} + \\ &(1-\beta-\gamma)c_{it-1} + \varphi k_{it-1} + u_{it} \end{aligned}$$

Small letters represent log differences or growth rates so that e.g. $q_{it} = \ln Q_{it} - \ln Q_{it-1} \approx \frac{\Delta Q_{it}}{Q_{it}}$. u_{it} is the first difference of ($\alpha_i + \varepsilon_{it}$). Note that the firm fixed (level) effect, α_i is differenced out of the transformed error term.

[10] The variations stem from whether to use total production, value added, TFP, “partial productivity” or labour productivity as left hand side variables, whether to use the knowledge capital stocks or the R&D intensity as the key right hand side variable, whether to impose constant return to scale in traditional inputs, whether to estimate equations in levels or first differences, the level of aggregation, what additional control variables to include, whether and how to handle simultaneity between input choice and production, whether to correct for double counting of inputs used for R&D, estimation method, etc.

[11] R&D man hours should have been subtracted to avoid double counting of R&D inputs. It seems, however, that such an adjustment creates substantial noise in our TFP measure due to measurement errors in the available R&D man year variable. According to Wieser (2005), lack of double counting causes a downward bias in the rate of return to R&D estimates. This is probably more important for estimates based on level equations than on growth equations where unobserved firm fixed effects are differenced out.

If we assume perfect competition, the elasticity of labour is $\beta = \frac{w_t L_{it}}{P_t Q_{it}}$ where w_t is the wage rate, and P_t can be normalized to 1 since Q_t is measured by sales.[12] We can then calculate $\hat{\beta}$ as the firms' wage share in output. Likewise, $\hat{\gamma}$ can be calculated as the firms' share of material costs in output. This makes it possible to rewrite equation (3) in TFP growth

$$(4) \quad tfp_{it} = a + \varphi k_{it-1} + u_{it}$$

where *tfp* is the log difference of TFP and $\ln TFP_{it} \equiv \ln Q_{it} - \hat{\beta}\ln L_{it} - \hat{\gamma}\ln M_{it} - (1-\hat{\beta}-\hat{\gamma})\ln C_{it}$.

When calculating the elasticities, we allow them to vary between firms, but assume that they are positive and fixed within firms over time.

Next, if we assume that the returns to knowledge capital, $\frac{\partial Q_{it}}{\partial K_{it}} = \rho$ is equated across firms, we can rewrite (4) as

$$(5) \quad tfp_{it} = a + \rho\left(\frac{\Delta K_{it-1}}{Q_{it-1}}\right) + u_{it}$$

since $\varphi = \frac{\partial Q_{it-1}}{\partial K_{it-1}} \frac{K_{it-1}}{Q_{it-1}}$ and $k_{it-1} \approx \frac{\Delta K_{it-1}}{K_{it-1}}$.

If knowledge capital depreciates slowly and knowledge accumulates additively, we have that $\Delta K_{it-1} \approx R_{it-1}$ where R_{it-1} represents total R&D investments in the previous period. This gives us the following relationship where the returns to R&D, ρ, can be estimated directly without calculating the knowledge capital stock

$$(6) \quad tfp_{it} = a + \rho\left(\frac{R_{it-1}}{Q_{it-1}}\right) + u_{it}.$$

R_{it}/Q_{it} is known as "research intensity". Not having to calculate the knowledge capital stock is beneficial since long time series of the firms' R&D investments typically are unavailable.

As we have indicated in footnote 10, 12 and throughout, there are many potential pitfalls in the framework leading up to equation (6). Even though ρ clearly tells us something about the effect of R&D on firm performance, its interpretation as "rate of return" should not be taken entirely literally. See e.g. Mairesse and Sassenou (1991) for a discussion of difficulties with this interpretation.

6.3. Extending the framework to allow for different types of R&D

We want to estimate the returns to different types of R&D separately. This suggests that we need to decompose the knowledge capital stock. We have assumed that the knowledge accumulation process is additive, i.e.

$$(7) \quad K_{it} = (1-\delta)K_{it-1} + R_{it}$$

R&D consists of different types of projects. Let us for know abstract from projects that receive R&D tax credits and focus on pure private funding and direct public grants. Theory predicts that projects financed by public grants are less efficient in building productive knowledge for the firm (in terms of generating private return) than projects that the firms undertake without subsidies.

Let us therefore distinguish between unweighted knowledge capital, K and efficient knowledge capital K^*. Let

$$(8) \quad K^*_{it} = K^P_{it} + (1+\pi)K^G_{it} \text{ and } K_{it} = K^P_{it} + K^G_{it}$$

Then $K^*_{it} = K_{it} + \pi K^G_{it}$.

P represents privately financed knowledge capital and *G* represents knowledge capital financed by grants from the government. We assume that both the private and governmental part of the knowledge capital accumulates according to (7).

The efficient knowledge capital is unobserved as the efficiency weight $(1+\pi)$ is unknown. However, if π is different from zero, equations (1) – (6) are misspecified. Taking the loglinear production function (2) as our point of departure, we find that the following term is missing

$$(9) \quad \begin{aligned} &\varphi\ln(K_{it} + \pi K^G_{it}) - \varphi\ln K_{it} \\ &= \varphi\ln\left(1 + \frac{\pi K^G_{it}}{K_{it}}\right) \approx \varphi\pi \cdot \frac{K^G_{it}}{K_{it}} \end{aligned}$$

Hence one possible solution is to include as a variable the ratio between the knowledge capital that is financed by the government and the total unweighted knowledge capital. This is the approach suggested by Griliches (1986). It makes it possible to estimate the efficiency parameter π by taking the ratio of the estimates for $\varphi\pi$ and φ.

[12] It is within this framework common to approximate elasticities with factor shares, but in the context of a model with R&D investments, perfect competition is obviously a rough, simplifying assumption. See Griliches (2000) p. 63-65 for a short discussion. According to Griliches, building on Klette and Griliches (1996), market power may lead to a downward bias of the estimated effect of R&D on productivity.

Note, however, that (9) involves an approximation, and that this approximation is only good for $\frac{\pi K_{it}^G}{K_{it}}$ close to zero. Furthermore, in order to make the correction term in (9), knowledge stocks based on both total R&D and governmental R&D must be calculated.

An alternative avenue, not explored by Griliches (1986), is to go back to equation (5). Substituting efficient knowledge capital for unweighted knowledge capital we get

$$(10)\quad tfp_{it} = a_t + \rho\left(\frac{\Delta K_{it-1}^*}{Q_{it-1}}\right) + u_{it}\,.$$

Next, we have that

$$(11)\quad \Delta K_{it}^* = \Delta[K_{it}^P + (1+\pi)K_{it}^G] = \Delta K_{it}^P + (1+\pi)\Delta K_{it}^G$$

Inserted in (10) this gives us

$$(12)\quad \begin{aligned} q_{it} &= a_t + \alpha c_{it} + \beta l_{it} + \gamma m_{it} + \rho\left(\frac{\Delta K_{it}^P}{Q_{it}}\right) \\ &+ \rho(1+\pi)\left(\frac{\Delta K_{it}^G}{Q_{it}}\right) + u_{it} \end{aligned}$$

where $\rho = \frac{\partial Q_{it}}{\partial K_{it}^P}$ and $\rho(1+\pi) = \frac{\partial Q_{it}}{\partial K_{it}^G}$.

The expressions for ρ og $\rho(1+\pi)$ follows from

$$(13)\quad \frac{\partial Q_{it}}{\partial K_{it}^P} = \frac{\partial Q_{it}}{\partial K_{it}^*}\cdot\frac{\partial K_{it}^*}{\partial K_{it}^P} = \frac{\partial Q_{it}}{\partial K_{it}^*} = \rho \text{ and}$$

$$(14)\quad \frac{\partial Q_{it}}{\partial K_{it}^G} = \frac{\partial Q_{it}}{\partial K_{it}^*}\cdot\frac{\partial K_{it}^*}{\partial K_{it}^G} = \frac{\partial Q_{it}}{\partial K_{it}^*}(1+\pi) = \rho(1+\pi)$$

The coefficients, ρ and $\rho(1+\pi)$, therefore can be interpretated as the returns to private and governmental knowledge capital respectively. If we again assume a low rate of depreciation so that $\Delta K_{it-1}^P \approx R_{it-1}^P$ and $\Delta K_{it-1}^G \approx R_{it-1}^G$, we can estimate (12) by using R&D intensities rather than knowledge capital stocks:

$$(15)\quad tfp_{it} = a_t + \rho\left(\frac{R_{it-1}^P}{Q_{it-1}}\right) + \rho(1+\pi)\left(\frac{R_{it-1}^G}{Q_{it-1}}\right) + u_{it}$$

So far we have for simplicity abstracted from R&D projects that receive tax credits. The framework we have developed, however, is easy to generalize to an arbitrary number of knowledge capital components. Let the knowledge capital built up on R&D projects that receive an R&D tax credit be K^T. Let its efficiency relative to privately financed knowledge capital be $(1+\tau)$. Then

$$(16)\quad K_{it} = K_{it}^P + K_{it}^G + K_{it}^T,$$

$$(17)\quad K_{it}^* = K_{it}^P + (1+\pi)K_{it}^G + (1+\tau)K_{it}^T = K_{it} + \pi K_{it}^G + \tau K_{it}^T$$

and

$$(18)\quad \Delta K_{it}^* = \Delta K_{it}^P + (1+\pi)\Delta K_{it}^G + (1+\tau)\Delta K_{it}^T$$

The equation to be estimated is then

$$(19)\quad \begin{aligned} tfp_{it} &= a_t + \rho\left(\frac{R_{it-1}^P}{Q_{it-1}}\right) + \rho(1+\pi)\left(\frac{R_{it-1}^G}{Q_{it-1}}\right) \\ &+ \rho(1+\tau)\left(\frac{R_{it-1}^T}{Q_{it-1}}\right) + u_{it} \end{aligned}$$

In the empirical application, we add time dummies, industry dummies and a dummy for firms that report zero R&D. We will also allow u_{it} to have a firm specific random component.

6.4. Data

Our sample consists at the outset of all observations in the Norwegian R&D surveys from 1993 to 2005. We merge these data with Statistics Norway's "firm capital database" that has detailed information on output and inputs for manufacturing firms. This database is documented in Raknerud, Rønningen and Skjerpen (2004, 2007) and Raknerud and Rønningen (2004). We remove observations with missing variables and outliers defined as observations with R&D-intensities large than 0.5 and TFP-growth (log difference) outside the ±50 % interval. These two trimming criteria remove about 2.5 % of the sample.

We assume that direct subsidies are given as matching grants and calculate R^G, R&D projects financed by public grants, as two times the grant. R^T is measured as the size of the R&D project accepted under the tax credit scheme, i.e. about five times the actual tax credit given that the project does not exceed the maximum amount liable for deduction. R&D projects financed by own funding is calculated as total R&D minus the two other components.

6.5. Results

We start out estimating equation (6) giving the overall return to R&D. The results are reported in table 6.1, column (1). Our overall estimate suggests a 15 % gross private return to R&D investments. This estimate seems low. R&D investments should earn a risk premium and "gross" means that depreciation is not accounted for (assumed to be zero).[13] Measurement

[13] Depreciation of the existing knowledge capital stock has to be deducted before the "net" return can be calculated. Depreciation of the private stock of knowledge capital is commonly assumed to be 15 %.

errors in the R&D variable are likely to give a downward bias, however, and our estimate is in line with the international literature and previous work on Norwegian data, see the next section.

In table 6.1, column (2)-(5), we explore whether the return varies with two measures of firm size. This can also be thought of as a robustness exercise as it shows the stability of the results across different subsamples. All samples give reasonable estimates. We find that SMEs and firms with pre SkatteFUNN R&D below 4 million have somewhat higher returns to R&D than larger firms.[14]

Our aim is to estimate the returns to R&D funded by direct subsidies and tax credits. Before turning to the framework developed in section 6.2 we explore this issue by using a simple dummy approach. In table 6.2, column (1), we see that interaction terms between R&D intensity and dummies for receiving direct subsidies and/or tax credits suggest that the return to R&D in firms that use the tax credits scheme is higher than the return to R&D in firms that receive direct R&D subsidies – at least for firms with high R&D intensity. The results in column (2)-(5) show that the basic pattern found in column (1) is fairly robust to various ways of splitting the sample.

Estimates based on our main specification in equation (19) are given in table 6.3. The pattern found in table 6.2 is confirmed. Our estimate for the return to R&D projects financed by direct subsidies is not significantly different from zero and the point estimate is actually negative. Our estimate for the return to R&D projects financed by tax credits is just slightly below the return to R&D projects financed by own funds. Although the estimated return to projects financed by direct subsidies is surprisingly low, the basic pattern fits the predictions given in section 5.1. R&D subsidies are given to projects with low private returns while projects that receive an R&D tax credit are quite similar to projects financed by own means, but have slightly lower returns. Remember that the key success criteria for projects financed by direct subsidies are their social returns which we do not estimate.

Turning to table 6.3, column (2)-(5), we find that the estimated pattern is quite robust to splitting the sample according to firm size. The estimated returns are however, not stable over time. When estimating the return parameters year by year from 1993 to 2005, they vary considerably. This may suggest a problem with the specification, but it may as well reflect a reality with large variance in the returns to R&D projects. Typically, a few projects are major successes while most projects have a low or negative return, see e.g. Scherer and Harhoff (2000). Cappelen, Raknerud and Rybalka (2007b) document that this is the case also for firms receiving SkatteFUNN-subsidies.

Table 6.1. Returns to R&D investments in Norway

	(1) All firms	(2) SME	(3) Large firms	(4) Below 4 million	(5) Above 4 million
$R\&D_{t-1}/Sales_{t-1}$	0.15***	0.19***	0.11***	0.17***	0.11***
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
R-square	0.03	0.04	0.03	0.03	0.04
No. of obs.	12081	7544	4537	9646	2435

The dependent variable is TFP-growth measured by log differences. Standard errors are in parentheses. The estimation method is GLS with firm random effects in the error term. A dummy for zero R&D, time dummies and 30 industry dummies are included, but not reported. Below and above 4 million refers to average intramural R&D being above or below the 4 million cap before the tax credit scheme was introduced. The sample consists of observations in the R&D surveys from 1993 to 2005. Outliers, defined as observations with R&D-intensities large than 0.5 and TFP-growth outside the ±50 % interval, are removed.

* Significant at the 10 percent level** Significant at the 5 percent level*** Significant at the 1 percent level.

Table 6.2. Returns to R&D by source of funding – interaction terms

	(1) All firms	(2) SME	(3) Large firms	(4) Below 4 million	(5) Above 4 million
$R\&D_{t-1}/Sales_{t-1}$	0.14***	0.14***	0.19***	0.11*	0.11*
	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)
Dummy for direct $subsidies_{t-1}$	0.01*	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Dummy for tax $credit_{t-1}$	-0.01**	-0.01*	-0.00	-0.01	-0.02***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
$R\&D_{t-1}/Sales_{t-1}$ * Dummy for direct $subsidies_{t-1}$	-0.10*	-0.09	-0.16**	-0.10	-0.10
	(0.06)	(0.08)	(0.08)	(0.09)	(0.08)
$R\&D_{t-1}/Sales_{t-1}$ * Dummy for tax $credit_{t-1}$	0.12**	0.15**	-0.06	0.17**	0.12
	(0.05)	(0.07)	(0.08)	(0.08)	(0.08)
R-square	0.03	0.04	0.03	0.03	0.05
No. of obs.	12081	7544	4537	9646	2435

The dependent variable is TFP-growth measured by log differences. Standard errors are in parentheses. The estimation method is GLS with firm random effects in the error term. A dummy for zero R&D, time dummies and 30 industry dummies are included, but not reported. Below and above 4 million refers to average intramural R&D being above or below the 4 million cap before the tax credit scheme was introduced. The sample consists of observations in the R&D surveys from 1993 to 2005. Outliers, defined as observations with R&D-intensities large than 0.5 and TFP-growth outside the ±50 % interval, are removed.

* Significant at the 10 percent level** Significant at the 5 percent level*** Significant at the 1 percent level.

Table 6.3. Returns to R&D by source of funding - intensities

	(1) All firms	(2) SME	(3) Large firms	(4) Below 4 million	(5) Above 4 million
$R\&D^{Own\ funding}/Sales$	0.19***	0.25***	0.13***	0.19***	0.16***
	(0.04)	(0.05)	(0.05)	(0.06)	(0.05)
$R\&D^{Direct\ subsidies}/Sales$	-0.09	-0.11	-0.01	-0.02	-0.14*
	(0.06)	(0.08)	(0.10)	(0.11)	(0.08)
$R\&D^{Tax\ credit}/Sales$	0.16***	0.17***	0.17	0.19***	0.12**
	(0.04)	(0.04)	(0.17)	(0.06)	(0.06)
R-square	0.03	0.04	0.03	0.03	0.05
No. of obs.	12081	7544	4537	9646	2435

The dependent variable is TFP-growth measured by log differences. Standard errors are in parentheses. The estimation method is GLS with firm random effects in the error term. A dummy for zero R&D, time dummies and 30 industry dummies are included, but not reported. Below and above 4 million refers to average intramural R&D being above or below the 4 million cap before the tax credit scheme was introduced. The sample consists of observations in the R&D surveys from 1993 to 2005. Outliers, defined as observations with R&D-intensities large than 0.5 and TFP-growth outside the ±50 % interval, are removed.

* Significant at the 10 percent level** Significant at the 5 percent level*** Significant at the 1 percent level.

[14] SMEs are defined according to the 2002 SkatteFUNN rules.

6.6. Previous estimates of the returns to R&D

There is a large international literature on the returns to R&D. Good surveys are provided byMairesse and Sassenou (1991), Griliches (2000), and Wieser (2005) performing a meta-analysis. Wieser concludes that there is "a large and significant impact of R&D on firm performance on average. However, the estimated returns vary considerably across studies".In the meta-analysis, he finds that "the estimated rates of return do not significantly differ between countries".

Taking the average over 32 studies with significant direct estimates of the rate of return to R&D, Wieser finds a private rate of return to R&D of 28 % with a standard deviation of 13 %. The corresponding results we have presented based on Norwegian data, 15 %, is therefore on the low side, but no means unusual. The significant estimates presented by Wieser range from 7% to 69 %. Including insignificant results, the average return is 16 % and the lowest estimate is –55%.

The most important previous study using Norwegian data is Klette and Johansen (1998). They analyse a panel of manufacturing plants with data from 1980 to 1992. They measure R&D at the line-of-business level within firms, and present estimates based on several specifications. When using the Griliches R&D-capital framework that we base our analysis on, they get gross rate of return estimates ranging from –17% to 51%, depending on the specification. The mean and median values across their 17 estimates are 12 % and 6 % respectively. The specification most similar to what we use in table 6.1 gives an estimated rate of return that is very close to zero. Their preferred estimate is, however, based on an alternative framework with a multiplicative knowledge capital accumulation function replacing equation (7) above. Their basic premise is that new R&D investments and the previous stock of knowledge are complements, meaning that the more you already know, the more new knowledge you can generate with a given R&D effort. Based on a model incorporating this idea, they find a net return to R&D around 9 percent, and that the depreciation rate from a private point of view is 15-18 percent. Their finding implies a rate of return to R&D that is quite close to estimates for the rate of return to physical capital investments.

We are not aware of any studies that compare the returns to different types of public R&D subsidies. Our framework in section 6.3, build on Griliches (1986) who compares the returns to commercial R&D with private and public funding. In line with our results, he finds a large premium on privately financed R&D. His estimates imply that privately financed R&D has a rate of return that is 50 to 180 percent large than the rate of return to publicly financed R&D.

On Norwegian data, Cappelen, Raknerud and Rybalka (2007a) analyse the effect of R&D financed by SkatteFUNN on firm productivity. Their study is part of the same evaluation program as our report. We complement their analysis in that our focus is on the relative merit of the tax credit vs. direct subsidies. There are also other differences. Cappelen et al. explore several specifications. Some of them are closely related to our framework, but some of them are econometrically far more advanced with respect to productivity measurement and dynamics. The econometrically advanced frameworks come at a cost, however. They demand more from the data. For this reason the analyses in Cappelen et al. is done on a smaller sample than our analyses. In what follows, we compare their results to ours, focusing on the parts that are most closely related.

Cappelen et al., table 2 is based on the knowledge stock approach similar to our equation (4), but in levels, not first differences. They use labour productivity as their left hand side variable, and assume that the effect of physical capital is absorbed by a random time invariant firm component in the error term.[15] They include various control variables and allow the time varying part of the error term to be first order auto-regressive. The model is estimated by GMM, and they find an overall net return to R&D around 12 %. Using a modified specification, they report 8 % in Cappelen et al (2007b). They find no significant difference between R&D financed by SkatteFUNN and other R&D, comprising both privately financed R&D and R&D financed by direct grants.[16] In section 6.4 above, we tend to find a somewhat lower return to SkatteFUNN R&D as compared to privately financed R&D, but then R&D financed by direct subsidies is treated separately.

In table 3, column (1) Cappelen et al. use an R&D intensity approach very similar to our table 6.1 column (1). The main difference is that they use labour productivity where we use TFP and they use OLS while we use random effects GLS as estimation method. They do not control for capital, but otherwise they include more control variables than we do. They find a gross rate of return equal to 13 % in their sample of 2349 firms from the years 2002 to 2005. This is quite close to our 15 % based on a sample of 12 081 firms from the years 1994 to 2005. They include in their specification a dummy for firms applying for SkatteFUNN and find that labour productivity growth of these firms does not differ from non-applicants in the year they apply. Note that this is quite different from what we do in table 6.2 where we explore the returns to R&D in SkatteFUNN firms by interacting a

[15] This is modified in Cappelen et al (2007b).

[16] Cappelen et al (2007a) find a slightly positive effect. Using a modified specification, Cappelen et al (2007b) find a slightly negative effect. None of the effects are significant.

dummy for receiving the tax credit with the R&D intensity, both lagged one year.

The main specification in Cappelen et al is a structural model of supply and factor demand with R&D capital. The basic framework is developed in Klette and Raknerud (XX). The main advantage of this framework is that it incorporates monopolistic competition and models explicitly the simultaneity between productivity and the choice of factor inputs, cf. footnote 12. Their general result is that SkatteFUNN has a weak, but positive effect on firm performance. The framework allows them to calculate the overall rate of return to the SkatteFUNN subsidy by industry and year. They find a positive, but modest return. Their estimates vary between 1 % and 7 % with 3 % as the median return. The return tends to increase over time.[17]

[17] This is more evident in Cappelen et al (2007b) where data from 2005 is included.

7. Conclusions

This report first investigates how participation in the Norwegian R&D tax credit scheme affects probability of receiving other R&D and innovation subsidies. We find no evidence suggesting that the R&D tax credit increase the probability of receiving direct R&D subsidies in the future, but we cannot exclude the possibility of an immediate positive effect. At the individual firm level direct subsidies and the tax credit seems to be complements, while at the innovation system level they seem to be substitutes as the probability of receiving direct subsidies has fallen after the introduction of the tax credit scheme. Next, we compare the additionality of the R&D tax credit with direct R&D subsidies. Our preferred estimate suggests that each public krone spent on tax credits for firms investing below the 4 million cap on intramural R&D increase private intramural R&D by 2.68 krone. This estimate builds on an assumption of zero additionality for firms above the 4 million cap. We find that the additionality of subsidies awarded through the Research Council and Innovation Norway is 2.07 and 1.53 respectively. The additionality of grants awared by ministries and other public agencies is 0.64, and the additionality of R&D subsidies from the EU is 0.75. We stress the potential for both positive and negative biases in these estimates.

Direct subsidy programs have public agencies involved in choosing the R&D projects that receive financing. Their aim is to select projects with large externalities that would not have been undertaken without the subsidy, i.e. projects that have a low private return. A tax credit, on the other hand has no such selection process attached to it, hence firms will rank projects according to their private return. Much of the subsidy will then be paid to inframarginal projects that would be undertaken even without a subsidy, i.e. projects with a high private return. The mechanism utilized by the government is simply to induce more R&D by lowering the marginal price. If the different subsidy schemes work according to "theory", projects should differ with respect to private returns depending on their source of financing.

We develop a framework for estimating the returns to R&D projects with different type of funding, and find support for this prediction. We find that projects funded through direct grants have essentially zero returns. Direct R&D subsidies are meant for projects with low private return and high social return. Our finding is therefore consistent with a high quality grant allocation process. The actual point estimate is probably downward biased due to measurement errors.

Our estimate for the return to R&D projects financed by tax credits is just slightly below the return to R&D projects financed by own funds. The estimated returns are 16 % and 19 % respectively. These estimates are surprisingly low for two reasons. First, R&D investments are considered to have high risk, and should therefore earn a risk premium. Second, the estimates represent "gross" returns, meaning that depreciation of the knowledge capital stock is not accounted for. As mentioned above, however, the estimates are likely to be downward biased by measurement errors. Furthermore, there is large variance in the returns to R&D projects. When we estimate the return parameters year by year, we find that they vary considerably around the estimated mean value in our sample period.

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