Spin-offs and spillovers: Tracing knowledge by following employees across firms *

by

Jarle Møen [‡]

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Abstract:

Most R&D projects fail from a commercial point of view, and technological shifts may quickly turn even successful innovations into failure. It is, however, possible that projects which fail commercially produce knowledge with some social value. Such knowledge is likely to be embodied in workers or teams of workers, and in order to evaluate the social returns to research, it is desirable to trace workers as they move across firms and industries. In this paper I utilize a large matched employer-employee data set and test for the existence of potential knowledge spillovers transmitted through the labor market. The specific case analysed is a series of Norwegian IT-programs so far considered unsuccessful, but which recently have been linked to the rise of a new generation of successful IT-firms. It has been argued that know-how and networks built up in leading companies during the programs still 'fertilize' the Norwegian IT-industry. I find little support for this claim. Workers with experience from companies that received R&D subsidies were largely re-employed in IT-industries, but they have not outperformed similar workers without such experience. An analysis of firms that are spin-offs from formerly subsidized IT-firms reveals that they perform below, rather than above average.

JEL classification: J24, J31, J62, O32

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‡ Norwegian School of Economics and Business Administration, Department of Finance and Management Science, Hellevn. 30, 5045 Bergen, Norway; and Statistics Norway, Research Department. E-mail: jarle.moen@nhh.no. http://www.nhh.no/sam/cv/moen-jarle.html Tel: + 47 55 95 95 49. Fax: + 47 55 95 95 43.

1 Introduction

Most R&D projects fail from a commercial point of view[1], and technological shifts may quickly turn even successful innovations into failure. This reflects the high risk associated with research, but also that it is difficult to appropriate the returns to knowledge. For this reason it is possible that projects and firms that fail commercially still produce knowledge with some social value. This possibility seems particularly relevant for subsidized R&D, since subsidies are aimed at projects with high risk and large externalities. The substantial amount of money spent by OECD governments on R&D subsidies makes it important to test this hypothesis[2]. A possible 'scrap value' associated with unsuccessful projects and firms may significantly influence the social returns to R&D and reduce the overall risk associated with technology programs[3]. This issue has so far not been investigated in the technology program evaluation literature, nor has there been much empirical analysis of labor market knowledge flows or spin-off firms in general.

This paper analyzes a series of Norwegian IT programs so far considered unsuccessful. Recently, however, it has been argued that knowledge built up in the subsidized firms has been transmitted to a new generation of successful firms through labor mobility. Using matched employer-emploee data, I test this hypothsis. Scientists and engineers with experience from the subsidized IT-firms have to a much larger extent than other scientists and engineers in high-tech industries migrated to the rapitdly growing IT service industry. There is no evidence, however, indicating that these scientists and engineers have played a particularly prominent role in the growth process. Nor do spin-off firms from the subsidized firms perform particularly well. 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.

The rest of this paper is organized as follows: The next section discuss labor market knowledge flows in more detail. Section three discuss the data, the empirical

[1]Cf. e.g. Scherer and Harhoff (2000). Analyzing several samples of innovations they find that the top ten percent most valuable innovations capture from 48 to 93 percent of the total value.

[2]According to Guellec and Pottelsberghe (2000) the OECD average share of governments in the funding of R&D performed by private firms was 10 percent in 1998. The share of government funding in total R&D was 30 percent.

[3]Scherer and Harhoff (2000) find that the estimated distributions of the returns to innovations are so skewed that instability may extend to the level of a whole economy. The risk aspect seems particularly relevant for small economies. While a large country like the US can be fairly confident that it will host at least a few major successes like Microsoft, IBM or Intel, chance probably plays a large role when a small country like Finland becomes the host of a giant like Nokia. Furthermore, even if a small country succeed in breeding a major company, there is always the risk that the company will be wiped out by a future technology shock. The extent to which knowledge built up in high tech firms can be applied elsewhere in the economy and generate spin-offs, therefore, is particularly important for small countries spending money to subsidize commercial R&D.

approach and the definition of key variables. Section four gives a brief description of aggregate subsidies and growth in the Norwegian IT and high-tech industries, and analyzes the flow of scientists and engineers out of subsidized and non-subsidized firms. Section five analyze the value of experience from subsidized IT-firms using wage regressions on a sample of scientists and engineers with experience from high-tech and IT-industries. Section six analyze the performance of spin-off firms, while section seven concludes.

2 The importance of analyzing knowledge flows

Since research is a learning process, knowledge built up through failed projects and firms is likely to be embodied in workers or teams of workers. In order to assess the value of such knowledge, it is necessary to trace workers as they move across firms and industries seeking to maximize the returns to their human capital. Consider the early days of the semiconductor industry as an example of the potential importance of this approach. If evaluating the social returns to R&D contracts awarded pioneering firms such as Sprague Electric, Shockley or Fairchild based on the performance of these firms alone, it seems clear from historical accounts that the return would appear modest. Yet, it is well documented that key technologies later utilized in the semiconductor industry by tremendously successful companies like Intel, was developed in these early entrants and transferred by employees to new firms better suited to exploit the technologies commercially, see e.g. Holbrook et al. (2000), Jackson (1997) or Saxenian (1994).

The recent availability of large matched employer-employee data sets makes it possible to analyze statistically the importance of human capital and employee mobility suggested by such case studies[4]. Furthermore, tracing knowledge flows by following employees is not only relevant when firms fail. It can also be useful when analyzing particularly successful firms and technologies, since entrepreneurs often ‘cash out’ on their investments by selling their company to larger, established firms. In conventional, firm-level data sets, such companies disappear without there being any indication of what happened. This problem may be particularly important when evaluating programs targeted at start-up firms and small businesses[5]. Analysis of the opposite process, i.e. the formation of spin-off firms, is also facilitated within a framework where employees are followed over time and across firms. Employee mobility and spin-off firms are closely related phenomena. Again, consider the semiconductor industry as an example. According to Saxenian (1994, p. 31), writing about Silicon Valley,

[4]An alternative approach is illustrated by Almeida and Kogut (1999) analysing patenting and patent citation patterns among engineers that change employers.

[5]The Small Business Innovation Research (SBIR) program in the US would be an example of such a program, cf. e.g. Lerner (1999) and Wallsten (2000).

> "Many of the region's entrepreneurs and managers speak of Fairchild as an important managerial training ground. ... To this day a poster of the corporate genealogy of the scores of Fairchild spin-offs, hangs on the walls of many Silicon Valley firms."

In the present paper, I illustrate how the ideas outlined above can be implemented and analyzed. Matched employer-employee data are used to 're-evaluate' a series of Norwegian technology programs in the 1980s that subsidized IT manufacturing firms. A previous evaluation by Klette and Møen (1999) concluded that "the IT-programs were largely unsuccessful". Recently, however, 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. Norsk Data was a 'national champion' and a leading minicomputer company[6]. It was the second largest company on the Oslo Stock Exchange in the mid 1980s, but had considerable difficulties in adapting to the technology shift in the late 1980s represented by the introduction of PCs and open standards. In 1989 mass layoffs were unavoidable and in 1991 it closed down its manufacturing plants[7].

One expression of the idea that Norsk Data had a lasting impact on the industry, can be found in a publication from the Research Council of Norway (2000) presenting IT (ICT[8]) firms and technologies that have benefitted from R&D subsidies. In the introduction the Council states that[9]

> "[t]he bankruptcy in Norsk Data received much attention, and left the impression that the Norwegian ICT industry was severely injured. This was not the case. Know-how was embedded in the employees, and these employees were rather quickly absorbed by other Norwegian ICT-firms."

It may not be very surprising that the Research Council in this way tries to improve upon the public impression of Norsk Data, given that the firm had received

[6]The company experienced a 40 percent average annual sales growth from 1973 to 1986, and 50 percent average annual growth in profits during the same period. It was considered the third most profitable computer company in the world, and the stocks were traded in Oslo, Stockholm, Frankfurt, London and New York. Cf. Steine (1992) and articles published in the business press for more information about the history of this company.

[7]What little was left of the company went bankrupt in 1993.

[8]I do not make any distinction between the concepts IT - information technology - and ICT - information and communication technologies. The latter abbreviation is of more recent origin, and its use seems to be associated with the growth of the IT service sector.

[9]In my translation.

massive subsidies[10]. A similar, but even stronger statement, however, was made by Norway's leading engineering magazine, *Teknisk Ukeblad,* one year earlier. In the fall of 1999, this bulletin of the Norwegian Engineering Association wanted to elect the 'engineering achievement of the century'[11]. Second of ten nominees was Norsk Data. The magazine argued that this 'industrial adventure ... left behind a thousand professionals whose knowledge still fertilize Norwegian information technology"[12].

It seems that the statements quoted above are based on knowledge about a handful of cases. Both the Research Council and *Teknisk Ukeblad* mention e.g. Dolphin Interconnect Solutions, a company that came out of the R&D department in Norsk Data when it closed down. In 2000 a part of Dolphin was sold to Sun Microsystems and in the business press, the price was pictured as sensational. Such 'spin-off returns' from previous investments cannot be captured by ordinary microeconometric program evaluation methodologies which focus on the performance of the subsidized firms[13]. In order to evaluate whether Dolphin and similar cases are representative, a quantitative framework utilizing matched employer-employee data is called for.

3 Data and empirical approach

3.1 Data

The data used in this study come from four main sources: Governmental administrative records prepared by Statistics Norway, the biannual R&D survey conducted by the Royal Norwegian Council for Scientific and Industrial Research and Statistics Norway, the manufacturing statistics of Statistics Norway, and the statistics of accounts for non-financial joint-stock companies prepared by Creditinform and Statistics Norway. The Norwegian data are extraordinary in the sense that the en-

[10]Norsk Data was the largest recipient among firms subsidized by the National Program for Information Technology lasting from 1987 to 1990, and received more than 12 percent of the budget allocated to commercial R&D under the program. Given the size of the company, this does not necessarily imply that the subsidies were large relative to Norsk Data's private R&D investments, but money from the National Program for Information Technology came on top of subsidies from preceding programs and substantial public procurements which were used actively to help the company develop new technology throughout its history. Cf. Harlem et al. (1990) and Bjerkan and Nergård (1990).

[11]Cf. Valmot (1999). A list of all nominees is given in the same journal (Teknisk Ukeblad), August 12th 1999, pp 10-11.

[12]My translation. Spelled out in more detail: "All over Norway we see spin-off effects from the Norsk Data era; thousands of people that worked in or with Norsk Data built up know-how whose existence it is hard to imagine without this company. Many of these people started new firms together with old colleagues or business contacts, others have contributed with their experience in other sectors of the economy." The article was titled "The lighthouse of the Norwegian IT-industry".

[13]Cf. Klette, Møen and Griliches (2000) for a review.

tire working population can be traced across employers over more than a decade, and in the sense that extremely rich information is available both about the workers and about their employers. The data appendix gives further details and descriptive statistics.

3.2 Hypothesis

The hypothesis under consideration is whether the boom in R&D subsidies and R&D investments in the Norwegian IT manufacturing industry in the mid and late 1980s, later caused growth in this or other sectors of the economy. Establishing such a causal link is demanding and involves constructing a counterfactual situation for the firms and workers involved.

Compared to the standard program evaluation literature, cf. e.g. Heckman, Lalonde and Smith (1999), several complications are present. First, the 'treatment' is not dichotomous. R&D investments have both an intensity dimension and a time dimension. Moreover, there is no clear-cut start of the program as various technology programs have replaced each other for several decades prior to the period that can be observed[14]. Also, the selection problem, fundamental to all program evaluation where participation is not randomized, has a peculiar twist. There is a 'double selection' process where firms are selected into programs, and workers self-select into firms. Deciding on a relevant and valid comparison group under these circumstances is difficult.

My responses to the problems listed above will be as follows: First, with respect to the intensity and time dimension of treatment, I will use a regression framework so that continuous variables can be utilized in addition to a dichotomous classification, based on cut-off values. Next, with respect to missing data for previous programs, little can be done. I will, however, argue below that this is not a severe obstacle. Finally, my response to the potential selection problem will be to allow for individual fixed effects. A more explicit approach to the selection problem does not seem necessary. Negative selection is not particularly relevant since R&D programs are meant to stimulate high quality research[15], and positive selection creates a bias against my conclusion that the programs were not successful.

3.3 How to define 'treatment'

Defining high-tech, R&D firms and IT R&D-firms Treatment, in the context of this paper, is having experience from a subsidized R&D firm in the IT

[14] Cf. Klette and Møen (1999) for details.

[15] This is not to say that negative selection could not exist. Various political economy processes may lead the subsidies to troubled firms, cf. Klette and Møen (1999) for a discussion. Then, however, the programs would not look successful, nor be successful.

manufacturing industry. In principle, therefore, we would like to compare similar workers with experience from IT-firms with and without subsidies. However, it is difficult to define an IT-industry since information technology does not constitute a separate class in standard industrial classification schemes[16]. Too narrow a set of classes will leave out a lot of true IT-firms, whereas a broader set will include a lot of non-IT firms. I get around this problem by utilizing a unique variable in the R&D surveys which identify the IT-content in each firm's R&D investments. Using this variable in combination with R&D man-years, I define IT R&D-firms in the manufacturing sector as firms with an intensity[17] of IT-related R&D above 10 percent[18]. This definition is designed to exclude a large number of firms that perform small IT projects without having information technology as their main focus or being technologically advanced. Almost without exception, units classified as IT R&D-firms according to this criteria belong to ISIC 382-385, i.e. the machinery, electronics, transportation equipment and technical instruments industries[19]. I will hereafter refer to these industries together as 'high-tech'. Out of 1173 plants (constituting 957 firms) with known R&D in the high-tech industries in the period 1986 to 1991, 197 plants belong to 'R&D firms' having an intensity of total R&D[20] above 10 percent. Out of these, 108 belong to 'IT R&D-firms', i.e. firms having an intensity of IT-related R&D above 10 percent. There are on average 4.0 observations of each plant in the years 1986 to 1990[21].

Defining subsidized firms Since subsidies are awarded unevenly among recipients, there is also a problem of how to define a subsidized IT R&D-firm (hereafter referred to as a subsidized firm). For a subsidy to have an effect on a firm's research activities, it must be of some significance. Hence, any subsidy should not qualify, and I define the treatment group as IT R&D-firms with an intensity of subsidized IT-related R&D above 0.5 percent. For a treatment firm with an intensity of IT-related R&D at the lower limit, i.e. 10 percent, this implies that at least 5 percent of the firm's IT-R&D must be subsidized[22]. The criteria is designed so that all large

[16]Cf. e.g. OECD (2000). The Norwegian industrial classification scheme was based on ISIC rev. 2 until 1993/94. Since then NACE rev. 1 (ISIC rev. 3) has been used.

[17]R&D intensity is measured as R&D man-years per employee (per year) at the three-digit line of business level within firms. Cf. the data appendix for more information. In the text, I will not distinguish between firms and lines of business within firms.

[18]These variables are not available, nor as relevant, for the IT service sector. This sector will be defined using the OECD definition based on industrial classification codes.

[19]The equivalent NACE classifications are NACE 29-35.

[20]The sum of IT and non-IT R&D.

[21]Note that firms, and thereby plants, can change category between years. When giving the number of plants in different categories above, plants are counted as belonging to an R&D firm or IT R&D firm if it has this status in at least one of the years 1986-1991.

[22]I know for each firm the share of R&D that is classified as IT, but not the share of subsidies used in IT-projects. However, since the government had IT high on its agenda, I assume that R&D-

subsidy recipients known from other sources, that can be identified in the data, are included[23]. Out of 108 plants belonging to IT R&D-firms in the period 1986 to 1990, 79 belong to subsidized firms.

Defining the treatment period Data on individual workers start in 1986, and the era of large R&D subsidies ended in 1990, cf. Figure 1 below. Hence, I will consider the years 1986 to 1990 to be the 'treatment period'. As mentioned, there were targeted IT-programs prior to 1986, but I do not believe the lack of data from these early years is a severe restriction. The largest R&D subsidy program were in effect from 1987 to 1990, and the largest IT R&D contracts were awarded in the years 1985 to 1987[24]. Furthermore, with some stability in employment relationships, a certain persistence in program participation, and both a lag and some persistence in the effect of subsidies, there will be a positive correlation between the unobserved and the observed treatment. It is, however, somewhat unfortunate that workers cannot be observed in a pre-treatment period, so that a clean comparison of pre and post treatment wages can be undertaken as part of the program evaluation.

Categorizing workers I want to assess the value of the core technological know-how built up in the subsidized firms. This know-how is likely to be possessed by scientists and engineers, and my analysis will therefore focus on this group. With the treatment period lasting from 1986 to 1990, many scientists and engineers will have had several employers, and firms may also have changed subsidy status within this time interval. I categorize scientists and engineers as having 'experience from subsidized firms' if they are attached to a subsidized firm in at least one year. Similarly scientists and engineers are categorized as having 'experience from IT R&D-firms' and 'experience from R&D-firms' if they have at least one year experience from such firms in 1986 to 1990.

Using these definitions, there are 1755 scientists and engineers with experience from R&D-firms. Out of these 1290 have experience from IT-R&D firms. In this group 1095 have experience from subsidized firms. About a quarter of the workers in subsidized firms were employed by the industry leader, Norsk Data. The numbers are based on a sample of male scientists and engineers born after 1935 and employed

subsidies awarded firms that report to do IT R&D is related to their IT-projects. If subsidies exceed a firm's IT R&D-investments, the excess subsidies are excluded.

[23]The ten largest recipients received 35 percent of the funds. These firms were producing electronic products, telecommunication equipment, instruments and computers. According to Harlem et al. (1990), the ten largest recipients were Norsk Data, Autodisplay, EB Nera, Nordic VLSI, EB, LCD Vision, Seatex, Micron, Simrad Subsea and Alcatel/STK. The order reflects the size of the funding.

[24]The implementation and organization of the National Program for Information Technology is extensively documented in Harlem et al. (1990) and Buland (1996).

full time in a high-tech firm at least one of the years 1986 to 1990[25]. Altogether there are 3784 scientists and engineers in the sample. 3419 of these are in firms with known R&D-investments.

Continuous treatment variables The firm categories defined above are based on cut-off values for R&D intensities that are somewhat arbitrary, and that conceal a significant amount of variation in research and 'program' exposure. The intensity of R&D and subsidies varied between firms within each category, and within firms over time. Furthermore, workers may have stayed with several employers during the program years. In many of the analyses that follow it is possible to use such continuous variation in treatment, and therefore I construct a stock measure of experience in addition to the dummies. This is done by attaching to each worker information about his employers R&D investments, and adding up intensities in R&D, IT R&D and subsidized IT R&D over the years 1986 to 1991. I use these sums as measures of the human capital accumulated[26].

3.4 A description of workers and firms by treatment category

Descriptive statistics on workers and firms are given in the data appendix. IT R&D firms are concentrated in the following industries: Computer and office machinery, Other machinery, Radio, TV and communication equipment, Insulated cables and wires, Professional and scientific instruments, and Photographic and optical goods. Except for computers, non of these industries are dominated by IT R&D firms, however. Subsidized and non-subsidized IT R&D-firms coexist in all industries mentioned except in production of insulated cables and wires, where all workers belong to subsidized firms. Other R&D firms and non-R&D firms are represented in a wider set of subindustries than the IT R&D firms. These industries comprise the production of various types of machinery, electrical equipment and transport equipment[27].

An important thing to notice is that the larger part of the IT-industry received subsidies. There are 1095 scientists and engineers with at least one year of experience

[25] I have excluded women because they are known to have different career patterns and preferences than men, and do not constitute a large share of the labor stock in these industries.

[26] Since the intensities are measured in man-years per employee per year, the unit of the 'experience stocks' are years. This should not be interpreted literary, however. It will only be a precise measure of individual R&D experience if all workers participate equally in the firms' R&D projects. This is obviously not the case, and one should rather think of R&D intensities as proxies for how much there is to learn in a firm at a given time. Summing the intensities over the time dimension then gives a measure of on-the-job learning.

[27] About 82 percent of the worker-year observations are from firms with R&D information available. Out of the 26 subindustries listed, 19 have some IT R&D investments.

from subsidized IT-firms and 195 that only have IT experience from non-subsidized firms. Given that the authorities were determined to stimulate the IT-industry, this is perhaps not surprising, but it leaves a relatively small, and possibly non-random, control group. That being said, however, there are relatively few observable differences between workers in subsidized and non-subsidized IT R&D-firms. Scientists and engineers in non-subsidized IT R&D-firms are slightly younger, but appear otherwise similar to their colleagues in subsidized firms. Furthermore, my analysis is not dependent on this dichotomus classification, as I also utilize continuous experience variables as explained above[28].

Subsidized firms are somewhat larger, more unionized and more likely to have a rural location than non-subsidized firms. They are also more often foreign owned and younger. The most interesting difference, however, is that subsidized firms had significantly higher growth rates in the years preceding the awarded subsidies. Presumably, recent success must have been an important criteria when subsidies were awarded. With respect to intensity in R&D and IT-R&D the two group of firms are close to identical. 'Other R&D firms' are somewhat less R&D intensive than IT R&D-firms and have a slightly lower educational level, but they are on the other hand more capital intensive. Non-R&D-firms have an even lower educational level than R&D-firms and are more unionized and less often foreign owned. Non-R&D firms are clearly the oldest group of firms.

With respect to educational composition, subsidized firms are slightly more diversified with respect to the human capital they possess than non-subsidized firms. All R&D-firms, however, even non-IT firms, are highly intensive in various types of electrotechnical engineering skills. Non-R&D firms also employ many workers of this type, but mechanical engineers is the most dominant skill group in these firms.

Summing up the differences between subsidized and non-subsidized IT R&D-firms, the main impression left by the descriptive statistics is that workers in subsidized and non-subsidized firms are quite similar, although there are some differences between the two types of firms. In particular, the technology programs seem to have favored firms with rapid growth.

[28]This creates substantial variation, as subsidies were very unevenly distributed across firms. This was part of a long tradition where 'national champions' were considered important catalysts for growth.

4 A closer look at investments, performance and labor mobility

4.1 Industry investments and growth

In the mid 1980s, the Norwegian economy was booming. At the same time, a large number of firms received R&D subsidies from public technology programs. Also, significant IT-related R&D contracts were given to the defence industry, and in connection with the restructuring and modernization of the public telephone company. The upper graph in Figure 1 shows total R&D investments in the high-tech industries, i.e. ISIC 382-385 in the years 1984 to 1997. The middle graph shows the share of these investments that were labelled information technology by the firms. The lower graph shows the share of the IT investments that was subsidized. The three graphs display a very similar pattern, with strong growth until 1987, and then a decline until 1991. Several developments are behind these movements. First, after the general expansion in the mid 1980s, the economy went into a downturn lasting from 1988 to 1993. Next, as mentioned in the introduction, the leading technology firm, Norsk Data, ran into trouble in the late 1980s and went out of business in 1991. Finally, the technology programs and large R&D-contracts came to an end.

An interesting feature in Figure 1 is that R&D investments in IT did not pick up in parallel with the increase in total R&D investments when the economy started to recover. This may be interpreted as an indication that the technology programs did not produce a basis for new growth, at least not within the manufacturing sector.

The development of the subsidized firms is more clearly drawn out in Figure 2, comparing employment growth in subsidized firms with employment growth in other categories of high-tech firms. There is a strong decline in employment in subsidized firms[29]. Given this picture, the dismal conclusion of Klette and Møen (1999)[30], evaluating the technology programs based on firm level data, are not surprising. However, as discussed above and suggested by the quotes in the introduction, this interpretation may be misleading. A more positive way to read Figure 2 is to stress that workers were leaving the subsidized firms on a large scale, and that they may have contributed to growth elsewhere.

Figure 3 pictures the growth in the Norwegian IT industry, as defined by OECD,

[29]Employment in non-subsidized R&D firms and other R&D firms appears to fluctuate more than the other two categories simply because there are fewer workers behind these graphs. The strong decline in employment for non-subsidized IT R&D firms from 1992 to 1993 is driven by one single firm that ran into trouble. Much of the subsequent growth is due to the same firm recovering. The negative employment growth in subsidized IT R&D firms is not driven by Norsk Data alone. Leaving out this company does not alter the picture significantly. Furthermore, looking at sales growth gives a very similar picture, but then I am not able to keep track of plants which change industry classification from manufacturing to services.

[30]Cf. the introduction.

from 1995 to 1999. In these years the IT service industry grew considerably faster than the rest of the private sector. As suggested by the Research Council, workers from previously subsidized manufacturing firms may have played a role in this process.

4.2 Tracing workers out of the subsidized firms

A natural first step when analyzing R&D-spillovers brought about by labor mobility, is to see where the technical expertise in the subsidized firms became employed later on. The results of such an analysis are presented in Table 1. The first column shows the industry of occupation in 1997 for scientists and engineers with experience from subsidized firms. The main comparison group is scientists and engineers with experience from IT R&D-firms that were not subsidized. These are tabulated in column 2. Columns 3 and 4 give mobility patterns for scientists and engineers with experience from other R&D-firms in the high-tech industries, i.e. firms whose research activities were not strongly IT-related, and scientists and engineers without experience from R&D-intensive firms.

The main difference between subsidized and non-subsidized IT R&D-firms is that a much higher share of scientists and engineers from the subsidized firms has moved to IT-service industries[31]. 30 percent of scientists and engineers from subsidized IT-firms became employed in the IT-service industry[32] versus 14 percent of scientists and engineers with experience from non-subsidized IT-firms. The other columns show that the less IT and R&D intensive the firms, the less likely are the scientists and engineers to move to the IT service sector. The table suggests that the subsidized IT-activities were service related, or at least that the IT-service industry offered the best opportunities for scientists and engineers from subsidized firms when these firms closed down.

[31]IT service industries are defined according to OECD and with a few further refinements added by Statistics Norway, cf. Statistics Denmark (2000). Included sub-industries are Wholesale of radio and television goods (NACE 51433), Wholesale of office machinery and equipment (NACE 5164), Wholesale of machinery and equipment for trade, transport and services (NACE 51654), Telecommunications (NACE 642), Renting of office machinery and equipment including computers (NACE 7133), Hardware consultancy (NACE 721), Software consultancy and supply (NACE 722), Data processing (NACE 723), Database activities (NACE 724), Maintenance and repair of office, accounting and computer machinery (NACE 725), and Other computer related activities (NACE 726). Corresponding ISIC codes are 61131, 61235, 7202, part of 833 and all of 8323 which correspond to NACE 72.

[32]Looking separately at workers from Norsk Data, the share is as high as 46 percent.

4.3 A brief summary of some 'non-wage' labor market outcomes

The main message to take away from Table 1, is that *the possibility* of a link between R&D subsidies awarded in the 1980s and growth in the IT-service sector in the 1990s, is present in the data. Next, I investigate how workers from the subsidized firms actually performed in the labor market. Were e.g. workers from the subsidized firms "rather quickly absorbed" in the labor market, as claimed by the Research Council?[33]. Some indicators that can throw light on this issue are reported in Table 2. Row 1 reports the share of displaced workers[34] that did not become re-employed in the same municipality[35]. Row 2 reports the share of workers who participated in active labor market programs. Row 3 reports the average employment rate following the program[36], row 4 reports the share of workers who took further education and finally row 5 reports the share of workers that became self-employed[37]. Taken together, the results do not suggest that workers from subsidized firms had any particular difficulties in finding new jobs. Having established this, I will move on to analyze earnings.

5 Wage regression analyses

If know-how built up in the subsidized firms was not firm-specific and thus provided a basis for growth in other firms later on, we would expect experience from subsidized firms to have higher value in the labor market than experience from other firms. This assertion can be tested using extended Mincer (1974) wage regressions. Lacking a 'pre treatment' period, I start out exploring scientists and engineers' wage level during the program. Next, I investigate wage growth following the program and check the results obtained from these two analyses against the wage levels after the program. Given that know-how built up in the industry leader Norsk Data has been considered particularly valuable, and that about one quarter of all scientists and

[33]Cf. quoted in the introduction.

[34]I have defined a displaced worker as a worker with at least two years tenure who separated from a plant that downsized at least 25 percent in that year or over that year and next year.

[35]Note that what is measured is a change in their home address municipality, not merely a change in municipality of employment. The low number for workers from non-subsidized IT R&D firms is due to one large firm that went through a mass lay-off, and then rehired many of the workers, cf. the 'dip' for employment in non-subsidized IT R&D firms in Figure 2.

[36]Those not employed include everyone who are not employed and not under education, regardless of whether they are registered as unemployed or not. Part time workers are counted as part time unemployed.

[37]These numbers may be artificially low. Presumably, they do not include workers who are employed in joint-stock companies that they own themselves. Self-employed are included in the wage analyses presented in the next section.

engineers with experience from subsidized firms have worked for this company, I investigate the robustness off all results with respect to leaving out these workers[38].

5.1 The effect of R&D and subsidies on wages during the program

Several mechanisms related to R&D, IT and subsidies may possibly have affected wages during the program period. First and foremost, if scientists and engineers expected to accumulate more general knowledge in subsidized firms (or in IT firms in general) than in other firms, they should be willing to pay for this through lower wages[39]. To the extent that subsidized firms promoted more advanced technologies, and technologies considered to have a large future potential, such investments in general human capital are conceivable, although risk aversion and liquidity constraints may reduce the effect. Another mechanism, possibly affecting the wages, is that subsidized firms may have employed scientists and engineers of better (unobserved) quality. High-ability workers are necessary to develop frontier technologies, but high-ability workers may also have a preference for working in a technologically advanced environment[40]. The net effect of this on wages is not obvious. On one hand, high-ability workers have better outside options, but workers with a preference for technologically advanced firms may, on the other hand, accept wages below their outside option[41]. A final possible mechanism is unions. The wage level in subsidized firms would be affected if the workers were able to negotiate higher wages and thereby extract some of the subsidies as rents.

Table 3 explores the wage level for prime aged male scientists and engineers in high-tech industries in the program years by including measures of R&D, IT R&D and subsidized IT R&D in a standard wage regressions. Both a dummy variable approach (column 1 and 3) and a specification with continuous variables (column 2 and 4) are reported. The dummy approach utilizes the dummies for R&D firm, IT R&D firm and subsidized IT R&D firm described in section 2. Note that these dummies are nested in the sense that a subsidized firm is also an IT R&D firm which is also an R&D firm. In specifications with continuous variables, I use intensities

[38]This procedure is intended to avoid a detailed and explicit wage analysis of this single company and its employees.

[39]This follows from classical human capital theory, cf. Becker (1962, 1964) and the discussion in Møen (2001).

[40]The work of Almeida and Kogut (1999), Stern (1999) and others suggests that scientists and technical personnel have preferences regarding the technological environment they work in.

[41]Rosen (1986) provides a review of the theory of compensated differentials (equalizing differences). Stern (1999) shows that this mechanism has relevance for scientists in the private sector. This is, in the setting of my paper, supported by Steine (1992) who states that the company policy of Norsk Data was to pay the same as similar firms, or somewhat less. He adds, “[i]t was attractive to work in Norsk Data, so why be a wage leader?” (p. 50, my translation).

measured as the share of the work force doing R&D, IT R&D and subsidized IT R&D. These variables are also nested, so that in order to find the total effect of a marginal increase in IT R&D due to a subsidized project, all three of the reported coefficients should be added.

In all regressions, workers in non-R&D firms is the baseline comparison group. Non-reported control variables are listed in the subtext to the table. Among these variables are 15 dummies for different academic degrees, hence, scientists and engineers are compared within detailed educational groups.

In Table 3, column 1 and 2, I do not distinguish between subsidized and non-subsidized IT R&D, and from Part A of the table, using the full sample, we see that the wage level in IT R&D firms is significantly below the wage level in other R&D firms. The average discount is between 2 and 3 percent. Non-IT R&D, however, does not seem to affect wages. When distinguishing between subsidized and non-subsidized IT R&D, a puzzling pattern appears. The dummy approach suggests that the lower wage level is associated with work in subsidized firms while the specification with continuous variables suggests that the lower wage level is associated with work in non-subsidized firms.

A clue as to how these conflicting results can be reconciled can be found in Part B of the table where workers from Norsk Data are excluded. Column 1 and 2, suggest that the observed lower wage level in IT R&D firms is driven mainly by workers in Norsk Data. If Norsk Data received enough IT subsidies per worker to be classified as a subsidized firm, but had, relative to other firms, far higher total investments in IT R&D per worker, this may explain the observed coefficients in Part A, column 3 and 4. This is not inconceivable. When sources like Bjerkan and Nergård (1990) describe Norsk Data as a thoroughly subsidized company, they are not so concerned with direct R&D subsidies as with preferential public procurement, and Norsk Data is in this respect a special case[42]. The company is also special in a different respect relevant for my analysis. The company was famous for rewarding their employees with shares, something that received much attention in the business press. The discount that the employees received when buying shares was counted as taxable labor income and is therefore included in my wage measure[43], but the stock market price of the shares increased so rapidly and for so many consecutive years, that the employees were likely to value the opportunity to buy shares in the company highly and trade this off against ordinary wage compensation. Hence, some (but probably not all, cf. footnote 41) of the apparent discount associated with Norsk Data may be an artifact of the company's unusual compensation scheme and not a true compensating differential[44].

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[42]Cf. footnote 10.

[43]Cf. Steine (1992, p. 54-55).

[44]As far as I know, this wage policy was unique for Norsk Data at the time, as were their consistently rising stock price. I should also mention that stock options were not much used in

Looking at Table 3B, column 3 and 4, we see that even when workers from Norsk Data are excluded, there is to be a wage discount associated with workers in subsidized firms. Both the dummy specification and the intensity specification suggest that the discount is slightly less than 2 percent compared to non-subsidized IT R&D firms, although only the intensity specification produces a significant coefficient[45]. Above I have mentioned several mechanisms that may be behind this. In order to distinguish between some of these possible mechanisms, the analysis in Table 4 can be extended by interacting R&D variables with experience, thereby examining wage profiles rather than average wage levels. If the wage discount in subsidized firms is due to workers investing in general human capital, one would expect it to be associated with young workers taking a wage cut when entering the firms and then experiencing stronger wage growth as their expectations about the value of on-the-job training become fulfilled[46].

Table 4 gives the results of including R&D, IT R&D and subsidized IT R&D, interacted with workers' experience. In column 1 and 2, we see that scientists and engineers have a steeper wage profile in IT R&D firms than in other firms. Consistent with the idea that IT is a general technology, cf. e.g. Bresnahan and Trajtenberg (1995), these firms appear to offer lower wages early in the career in exchange for higher wage growth thereafter. The beginning wages in IT R&D-firms are about 10 percent lower than in other R&D firms, and the annual wage growth is about 0.5 percent higher[47]. Interestingly, there are no significant differences between R&D firms that don't specialize in IT and non-R&D firms.

Moving on to column 3 and 4, distinguishing between subsidized and non-subsidized IT R&D firms, one finds that the average wage discount associated with subsidies in Table 4 is due to the wage profile in subsidized firms being less steep

the sample years. Due to a very unfavourable tax treatment between 1991 and 1999, it was not much used in later years, either. For these reasons, I believe that labor earnings is a fairly accurate measure of monetary compensation in other companies than Norsk Data.

[45]For the intensity specification, the discount is derived by multiplying the coefficient -0.488 with 0.036, the employers' average intensity in subsidized IT R&D, from table A2.

[46]Workers may also pay for learning through lower wages later in their career, but that will be difficult to separate from the wage premia they receive on their previous human capital investments, cf. footnote 47 and Møen (2001). From a theoretical point of view, their willingness to invest in human capital should fall gradually towards retirement.

[47]The dummy and the intensity specification give very similar results. Taking into account the special wage policy of Norsk Data discussed above, and looking instead at part B, it may seem as if 10 percent is rather on the big side. If the correct wage discount for entering workers is between 6 and 7 percent, and the wage growth between 0.4 and 0.5 percent, as suggested in Part B, this imply a pay-back period of about 15 years. Notice also that the firms' IT R&D-intensity times experience is used as a proxy both for how much the workers are learning, and how much they have learned on the job, cf. Møen (2001). IT R&D-intensity is a noisy variable, and as a proxy for human capital, it probably becomes increasingly noisy the further into the career a worker has reached. This implies that measurement errors may severely bias the coefficient on the interaction term towards zero.

than the wage profile in non-subsidized firms. Hence, there is nothing in the data suggesting that investments in general human capital were particularly large for workers in subsidized firms.

5.2 The effect of experience from subsidized firms on wages later in the career

Table 5 contains the results of an analysis of the effect of experience from R&D, IT R&D and subsidized IT R&D-firms on ten year wage growth from 1986 and 1987 to 1996 and 1997. The advantage of looking at wage growth is that potential differences in ability and preferences between workers are accounted for, and looking at the full ten year interval takes one from one boom in the economy to the next. This is desirable, since it may be difficult to capture the full program effect before the labor market has adjusted to the many mass layoffs caused by the recession.

The sample consists of full time working male scientists and engineers, having at least one year full time experience from high-tech or IT industries, including services, in 1986-1997[48]. Workers without experience from manufacturing, and hence not part of the previous analysis, are included for two reasons. First, it has some interest to compare workers entering the expanding IT service industries with background from manufacturing high-tech industries to workers who have acquired most of their work experience within the IT-service industries[49]. Second, these workers help identify the many control variables in the wage regression, such as experience and dummies for industries, altogether 72 coefficients[50]. Given the relatively small number of workers with experience from non-subsidized IT firms, it is important to identify common coefficients as precisely as possible[51].

At first sight, the results in Table 5A, column 1 and 2, seem to imply that workers in IT R&D firms have had significantly higher wage growth than other workers. Looking, however, at column 3 and 4, and Part B, we see a pattern very similar to the one found in Table 3 and discussed in detail above. This suggests that the

[48] The sample industries are high-tech and IT, defined as NACE 29-35, 51433, 5164, 51654, 642, 7133 and 72. Cf. footnote 31 for more information.

[49] As it turns out, there does not seem to be any important differences between these groups, and I have not tabulated separate coefficients for workers that only have experience from IT service industries. On average, these workers seem to receive slightly lower wages than workers with experience from high-tech manufacturing.

[50] The industry dummies do not follow a particular NACE or ISIC level. Within high-tech and IT-industries I use a detailed categorization, usually at the five digit level. In less advanced sectors, with fewer observations in the sample, the dummies are usually at the two or three digit level. Cf. the subtext to Table 5 for a full list of control variables an other details regarding the regression.

[51] The assumption that there is a common experience profile, common industry effects and so on, is of course not obvious, but it seems to be a reasonable approximation. Furthermore, my conclusions are robust to reducing the sample size by excluding workers without experience from firms that have invested in IT R&D.

significant growth results are driven by a possible mismeasurement of compensation for workers in Norsk Data in the beginning of the period. When excluding these workers, there is only a small and non-significant wage growth effect left, i.e. workers with experience from IT R&D-firms have a slightly higher wage growth than workers with experience from other firms, and workers with experience from subsidized IT R&D-firms have a slightly higher wage growth than workers with experience from non-subsidized IT R&D-firms, without any of these differences being significantly different from zero.

Table 6 reports the results of an analysis of the effect of experience from R&D, IT R&D and subsidized IT R&D-firms in the program years on wages in the years 1996 and 1997. Consistent with tables 3 and 5, the results show that there are no significant differences related to these various types of experience. In particular, workers with experience from subsidized firms, started out with a small but significant (using the intensity specification) average wage discount, and had slightly higher, but not significantly higher, wage growth, and they have ended up with a slightly lower, although not significantly lower, wage level as reported in Table 6[52].

Changing the specification in Table 6 by including firm specific fixed effects, and thereby asking whether workers with experience from subsidized firms have ended up in the best paid positions within their firms, give very similar results to the specification without firm specific fixed effects and is not reported. With respect to workers with experience from Norsk Data, a detailed investigation of Table 6, contrasting Part A with Part B in light of the previous discussion of subsidies and IT R&D investments in this company, suggests that these workers have wages below the average for other workers with experience from subsidized firms[53].

Before concluding the wage analysis, one should reflect on how the results in Table 5 and 6 relates to Table 4 which indicated that workers in IT R&D-firms, whether subsidized or not, accepted a wage discount at the start of their career and experienced higher wage growth later on. If the estimated wage growth associated with a career in IT R&D firms had continued after the program period, it obviously should have caused a significant positive coefficient on experience from IT R&D firms both in Table 5 and 6[54]. When there is no such positive effect, it implies that these workers did not receive the return they expected. One possible interpretation is that their expectations did not come through because of the technology shifts in

[52] If including the years 1994 and 1995 in addition to 1996 and 1997, the coefficient on experience from subsidized firms in column 4 becomes marginally significant.

[53] If running a similar regression for skilled workers with secondary technical education, however, I find a significant positive wage premium for workers with experience from Norsk Data. This may suggest that scientists and engineers accumulate more firm specific human capital, and is more exposed to technological risk than workers with secondary technical education.

[54] In Table 6 this is so because the average worker with experience from IT R&D-firms, even if continuing to invest in on-the-job training by staying in such a firm, should have caught up with and passed workers without such experience by 1996/97.

the IT-industry in the late 1980s.

Tables 3 through 6, can be summarized in one sentence: *Scientists and engineers with experience from subsidized IT R&D-firms performed exactly as good, or rather as bad, as workers from non-subsidized firms.* Workers in all IT R&D firms seem to have 'co-financed' their employers' R&D investments by accepting wages below their alternative wage, presumably believing that work experience from these firms would provide general human capital. The expected wage growth, however, did not materialize after the program period, leaving them no return on their investment. With respect to workers in subsidized firms, they do not seem to have gained anything from participating in the subsidized projects. Consequently, *my analysis does not support the idea that the IT R&D programs created significant benefits for workers with experience from subsidized firms.* On the positive side, however, workers in subsidized firms did not perform particularly bad, either, even though many of them became displaced in the late 1980s as shown in Figure 2[55].

6 The performance of spin-off firms

A complementary approach to looking at the performance of individual workers, is to focus on the performance of spin-off firms defined by groups of workers that have stayed together. When several workers from the same firm continue to work together, it is reasonable to assume that they are exploiting know-how built up in their previous work environment, and that there are positive complementarities between them that make them stay together. It is also possible that firm profits is a better performance measure than wages, particularly if the spin-off firms to some extent are worker-owned. Low tax rate on capital income relative to labor income may induce employee-owners to substitute wages for return on stocks[56], and employee-owners may also sacrifice wages in order to finance firm growth[57].

6.1 Sample and definition of spin-offs

Tables 7 and 8 present the results of my analysis of spin-off firms. Roughly speaking, i.e. leaving out some of the finer details to be laid out below, I define *a spin-off firm*

[55]Note that I control for displacement in the wage regressions in Table 5 and 6, but the variable is not significantly different from zero. Distinguishing, however, between workers with experience from subsidized firms who have stayed with the same firm, and separators, I find a modest negative effect for separators (not reported). In the stock specification this negative effect is significant.

[56]Note, however, that the Norwegian tax system have detailed rules in order to avoid this type of tax evation.

[57]One may also think that employee stock options plans would reduce the relevance of taxable labor income as an earnings measure, and show up in firm profits. This kind of options, however, has been very unusual in Norway due to an unfavorable tax regime, cf. footnote 44.

as a firm that was not originally subsidized, but where at least 25 percent of the employees have experience from a firm that was subsidized.

The sample period is 1994-1997, i.e. the years when the IT industry recovered according to Figure 3. The sample consists of all non-financial joint-stock companies with more than one employee and at least one scientist or engineer, in industries with at least one 'program firm', i.e. a firm that to a large extent draw on human capital with experience from subsidized IT R&D firms. Formally, I define program firms as firms that have, at some point, had at least a 25 percent share of employees with experience from subsidized firms, and at least one scientist or engineer with experience from a subsidized firm. Any definition of this type will necessarily be a bit arbitrary, but the idea is to identify firms that draw significantly on knowledge that was built up under the program.

The definition of program firms does not distinguish between continuing subsidized firms that has retained experienced workers, and new firms, spin-offs, employing workers with experience from subsidized firms. This is because I want to start out by tracing all firms drawing on 'program know-how'. Utilizing information about plants, however, I can identify those of the program firms that represent a continuation of originally subsidized firms[58]. I label these 'continuing or reorganized subsidized firms'. This group of firms is defined as program firms that contain one or more plant that in 1986-1990 belonged to a subsidized firm. Program firms that do not fall into this category are defined as spin-off firms. According to the above definitions, there are altogether 109 program firms in the sample, 76 of these are spin-off firms and 33 are continuing or reorganized subsidized firms.

6.2 Descriptive statistics and results

Program firms are somewhat larger, more capital intensive, more R&D intensive, and more intensive in use of scientists and engineers, than non-program firms, cf. the data appendix. They are also somewhat younger and less often in a rural location. Spin-off firms are significantly younger and smaller than continuing or reorganized subsidized firms, as one would expect. Spin-offs are also less R&D-intensive, but more human capital intensive. This reflect that a larger fraction of the spin-off firms belong to service industries. 37 percent of the spin-off firms can be identified as spin-offs from Norsk Data.

The first performance measure I consider is simply sales growth. The results are reported in Table 7. Spin-off firms perform slightly better than other firms along this

[58] Firm identification numbers represent legal units, and will change if one firm or plant is bought by another firm, etc. Plant identification numbers, on the other hand, will change only if the production is physically moved or substantially altered with respect to industry classification. Not all registers that are matched to produce my data set, however, use the same plant and firm identification number system. For this reason the match between plants and firms, and the tracking of units over time, is slightly imperfect.

dimension, but the difference is not significant. Moving on to profitability, Table 8 presents return on sales, return on assets and return on equity. It shows that program firms are significantly *less* profitable than other firms. On average they have 1.2 percent lower return on sales, 3.2 percent lower return on assets and 15.5 percent lower return on equity.

Looking separately at spin-offs and continuing or reorganized subsidized firms, we see that the significant negative results are exclusively associated with the spin-off firms. It is difficult to explain these coefficients, but one possibility is that the spin-off firms mostly consist of troubled remnants of previously subsidized units, and that they are kept running because their core know-how has low alternative value[59]. Analyzing wages in spin-off firms (not reported), I find some support for this hypothesis. Scientists and engineers with experience from subsidized firms that work in spin-off firms, have a small wage discount. Workers with experience from subsidized firms that work in continuing or reorganized subsidized firms, on the other hand, have a significant wage premium[60]. This may suggest that the most valuable know-how built up under the program is to be found in the surviving plants and not in the spin-off firms. In any case, *my analysis does not give support to the idea that important returns from the IT-program ended up outside the originally subsidized firms.*

6.3 Robustness

In all the firm performance analyses presented above, I have controlled for firm age, firm size, intensity in use of scientists and engineers, current R&D-investments, business cycle effects, and industry differences. The main results are robust to leaving out these control variables, but without controls, also continuing or reorganized subsidized firms have a profitability below average.

Since the exact definition of program and spin-off firms is based on a somewhat arbitrary cutoff value for the share of employees that has experience from firms that received subsidies, it is particularly important to test the robustness of the results with respect to these definitions. I have tried both a more inclusive definition, looking at firms with a 10 percent share of employees with experience from subsidized firms, and a more exclusive definition looking at firms with a 50 percent share of employees with experience from subsidized firms. In both cases, the main results in Tables 8 and 8 hold true. Defining spin-offs based on the share of engineers with experience from subsidized firms, rather than the share of employees with experience from subsidized firms reduces the significance of the negative coefficients. Finally, I have looked specifically at spin-offs from Norsk Data. If anything, these firms have

[59] E.g. sales or service departments, or production teams that move to a new location and try to continue on their own.

[60] Cf. footnote 55, for a related non-reported analysis pointing in the same direction.

a weaker performance than other spin-off firms. With respect to a possible time trend in performance, cf. the strong industry growth present in Figure 3, I find that the profitability of the spin-off firms is falling over time.

Given that the returns to innovation is known to have a very skewed distribution, one may also question whether the regression analyses reported above correctly represent *aggregate* profits for the different categories of firms. A few large and profitable spin-off firms could possibly more than outweigh the low profits in the many small firms dominating the sample. One simple way to explore this issue is to pool all spin-off firms, all continuing or reorganized subsidized firms, and all non-subsidized and non-spin-off firms, in order to compute the joint performance of the various groups. The result of this exercise is graphed in Figure 4. When assessing the joint performance this way, spin-off firms as a group have a higher return on sales than non-spin-off firms, but they perform worse with respect to sales growth, return on assets and return on equity.

A final question one may ask with respect to robustness, is whether the results are specifically related to the subsidized IT R&D firms, or whether any spin-off from firms that invested in IT R&D in the late 1980s have performed similarly bad. I have looked at this question by defining spin-offs from all R&D firms and all IT R&D firms in the same manner as I have defined spin-offs from subsidized IT R&D firms. This analysis (not reported) show that the negative results are most strongly associated with spin-offs from subsidized firms. There are, however, only six spin-offs from non-subsidized IT R&D firms in the sample. In a related analysis (also not reported) I have regressed firm profitability on a continuous measure of different types of R&D experience among the firms' scientists and engineers. In this analysis, R&D-, IT R&D- and subsidized IT R&D experience is measured in the same way as in the wage regressions presented in Tables 5 and 6. The results do not confirm the negative effect of subsidies found in the spin-off analysis, but nor do firms whose scientists and engineers have particularly much experience from subsidized firms perform significantly better.

6.4 Remarks on profitability as performance measure

An objection to the spin-off analysis might be that current sales and profitability are not relevant performance measures in the IT industry, and that the spin-off firms may become successes in the long run. Admittedly, numerous companies in the "New Economy" have been unprofitable, and still highly valued in the stock market due to large investments in intangible capital. These arguments are not entirely convincing, however, as the stock market values such firms far less now than some years ago. Also, private owners buying a company where previous owners have lost their money, may make the company look successful and produce positive profits, without there being a positive *social* return to the historical R&D investments that produced the technology. Comparing total investments to expected future profits is difficult and requires case studies.

A particularly interesting case in the Norwegian IT-industry is Dolphin Interconnect Solutions. This company has been considered the most successful spin-off from Norsk Data, cf. section 2, but did not make positive profit in any of the sample years. The founding engineers started to develop the 'Dolphin SCI technology' in 1988 while still working for Norsk Data, and 1999 was the first year in history that the company generated positive profits[61]. Rough calculations suggest that total investments in Dolphin amounts to about NOK 500 million[62]. In 2000 a major part of Dolphin was sold to Sun Microsystems and the price, NOK 171 million, was considered very favorable. Per employee, the price was NOK 8 million, something which is more than 10 times the cost of an engineering man-year. However, if the part of the company sold to Sun represents more than one third of the total value of the company, the rate of return to Dolphin as an investments project has been negative. A market based evaluation, therefore, is not likely to make Dolphin come out as a large success.

7 Conclusion

This paper illustrates how matched employer-employee data can be used to assess whether human capital built up in subsidized firms is general or specific. The case considered is a series of Norwegian IT-programs from the mid and late 1980s. I find no evidence suggesting that experience from subsidized firms has been rewarded with a wage premium. Scientists and engineers with experience from subsidized firms receive on average the same wage as otherwise similar workers without such experience. This suggests that the return to the knowledge investments made by the government and the workers themselves, was zero. One possible explanation is that the technology shift in the late 1980s rendered much of the intellectual human capital built up under the programs obsolete.

Analyzing the performance of spin-off firms reinforces this dismal conclusion. Spin-offs from subsidized firms are less profitable than other firms, suggesting that the identified spin-offs to a large extent consist of troubled remnants of previously subsidized units. What keeps workers in these firms together may be a low alternative value of their know-how, rather than positive complementarities associated with successful innovations. In any case, my analysis does not give support to the idea that important returns from the IT-programs ended up outside the originally

[61] Cf. http://www.dolphinics.com.

[62] This number is calculated on the basis of articles written about Dolphin in the major newspapers Aftenposten, Dagens Næringsliv and Bergens Tidene in the years 1991-2001. The number is adjusted for inflation. Using an additional 7 percent discount factor, the total investment amounts to NOK 800 milll. About 20 percent of the investments has been financed by public subsidies.

subsidized firms.

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Data appendix

Information about individual workers comes from a number of governmental administrative records, which are prepared by Statistics Norway for research use. Barth and Dale-Olsen (1999), appendix 2, give some details on the various registers included in the data base. I have taken great care to improve the data quality by checking for consistency across years and across related variables for the same individual. Missing values are imputed where possible. The available registers cover the years 1986 to 1997. Earnings is measured as taxable labor income. I have referred to this as the workers' wage. The value of stock options received in the employment relationship is included in the workers' taxable labor income after 1991. The use of stock options, however, was negligible. Experience is measured as potential work experience, i.e. age minus schooling minus seven.

Workers with earnings less than 150 000 1995 NOK are considered part time workers, even if coded as full time employed, and are excluded from the wage regressions. Likewise, workers who have not worked for a full calender year are excluded, and also workers with missing educational information. Starting out with all male workers that have had some sort of affiliation with high-tech or IT industries in one of the years 1986 to 1997, and that were employed in at least one of the years 1986 to 1991, these trimming procedures reduce the total sample of worker-year observations with about 14 percent, somewhat less, 9 percent, for graduate workers.

Plant level information about employers comes from the annual manufacturing census of Statistics Norway[63]. Information about R&D at the line of business level within firms is collected from R&D surveys and other surveys of immaterial investments and innovation. Prior to 1991 the R&D surveys were conducted by the Royal Norwegian Council for Scientific and Industrial Research. In 1991 and later years, the surveys have been conducted by Statistics Norway[64]. I merge the R&D data to plants based on the plants' firm number and three-digit industrial classification code. This amounts to assuming that there are perfect R&D spillovers between plants belonging to the same line of business within multi-plant firms.

In the machinery and equipment industries utilized in this study, the R&D surveys have close to full coverage for firms with more than 20 employees. For years and firms not covered by the R&D surveys, three other data sets has been utilized. A survey of immaterial investments was conducted by Statistics Norway in 1988, covering the years 1986-88, and in 1990 covering the years 1988-90. Furthermore, an innovation survey was conducted by statistics Norway in 1993 for the year 1992. These sources, however, do not contain information about the share of R&D that is

[63]The census is documented in the series *Manufacturing statistics*, Official Statistics of Norway, Statistics Norway, Oslo. The microdata are documented in a mimeo from 1991 by Halvorsen, Jensen and Foyn in Statistics Norway.

[64]Microdata with the neccessary variables is available in 1984 and biannually 1985-97.

IT-related, and also have limited information about subsidies. The data appendix in Møen (2001) gives references to reports documenting the surveys, and describe in detail the procedures used to combine the various sources when constructing the R&D database. When possible, R&D-intensity and the share of IT-related R&D is imputed by linear interpolation, and by extrapolating the first observed value backwards in time and the last observed value forward in time, firm by firm. Firms' R&D investments are known to be stable over time, and the subsidy and share of IT R&D variables are only available from the biannual surveys. Imputing missing information when possible, therefore, is a desirable procedure. R&D subsidies is a less stable variable than the other two, however, and I have therefore extrapolated this variable only one year forward.

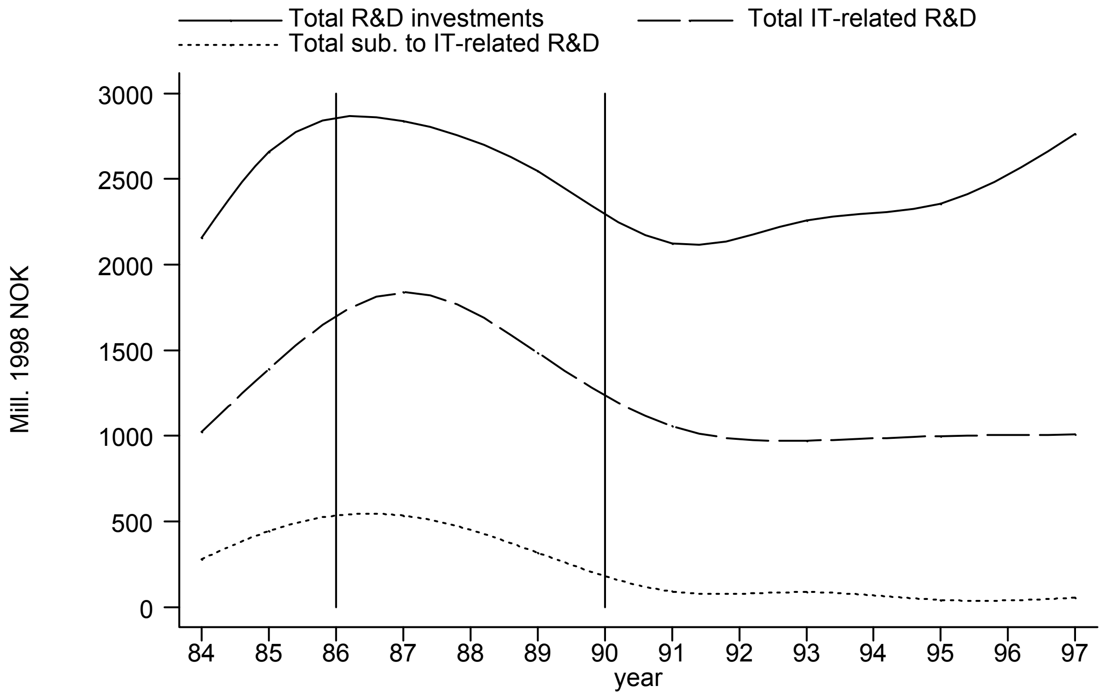
Having performed the imputations described above, about 18 percent of the worker-year observations still lack information about R&D-intensity, about 22 percent still lack information about IT R&D-intensity and about 25 percent still lack information about subsidies[65]. About 76 percent of the non-missing worker-year observations of R&D investments are from surveys, 5 percent are imputed by interpolation and 18 percent are imputed by extrapolation. About 62 percent of the imputed R&D intensities are zero. With respect to subsidized IT R&D investments, about 59 percent of the non-missing worker-year subsidy variables are from surveys, and the rest are imputed. About 73 percent of the imputed subsidized IT R&D intensities are zero. In the regressions, I account for missing R&D information by using dummies.

The analysis of spin-off firms is based on the statistics of accounts for non-financial joint-stock companies prepared by Creditinform and Statistics Norway[66]. The accounts statistics are from the enterprises' financial statements submitted annually to the Register of Company Accounts in Brønnøysund and cover in principle the entire population of non-financial joint-stock companies. An important advantage of this data base is that it has information about firms outside the manufacturing industry. Data are available from 1993. Firms with missing information about return on sales, assets or equity have been excluded. This reduces the sample with 8 percent. The influence of outliers is reduced by replacing values for return on sales, assets and equity below the 5th percentile with the 5th percentile, and values above the 95th percentile with the 95th percentile.

[65] For scientists and engineers the number is smaller, cf. Table A1.

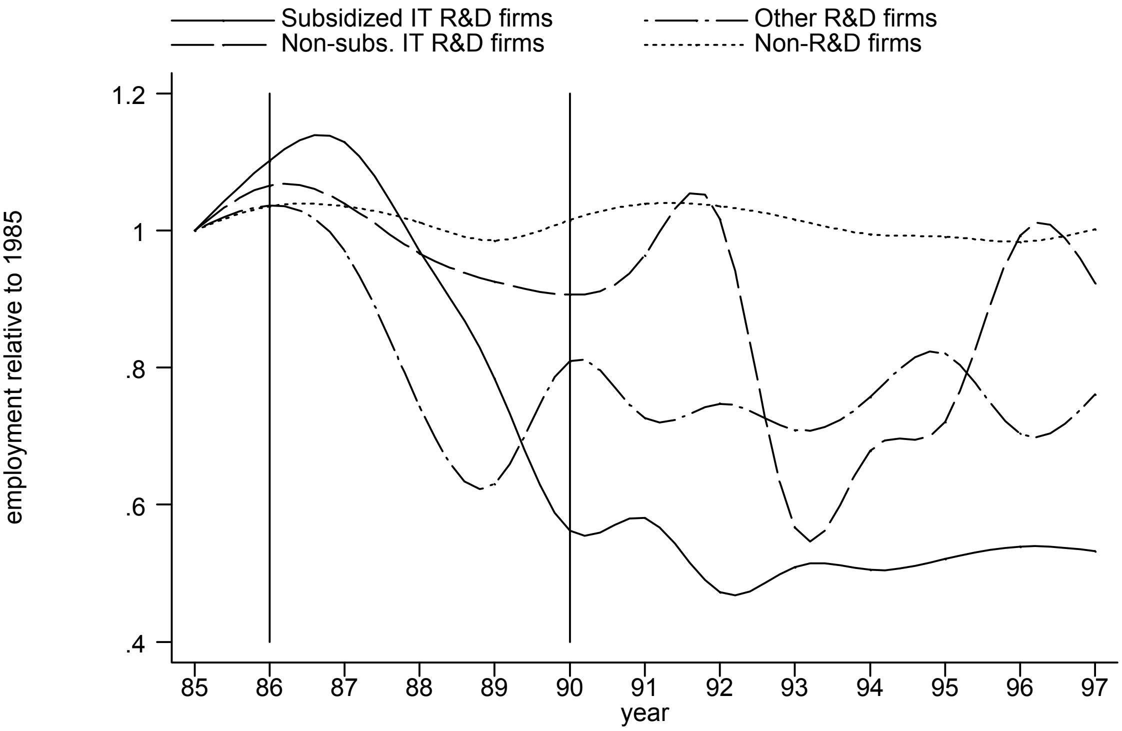
[66] Cf. the annual statistics of accounts for non-financial joint-stock companies, Statistics Norway, for documentation.

Figure 1: R&D investments, IT-related R&D and subsidies to IT-related R&D in high-tech industries in 1984-1997



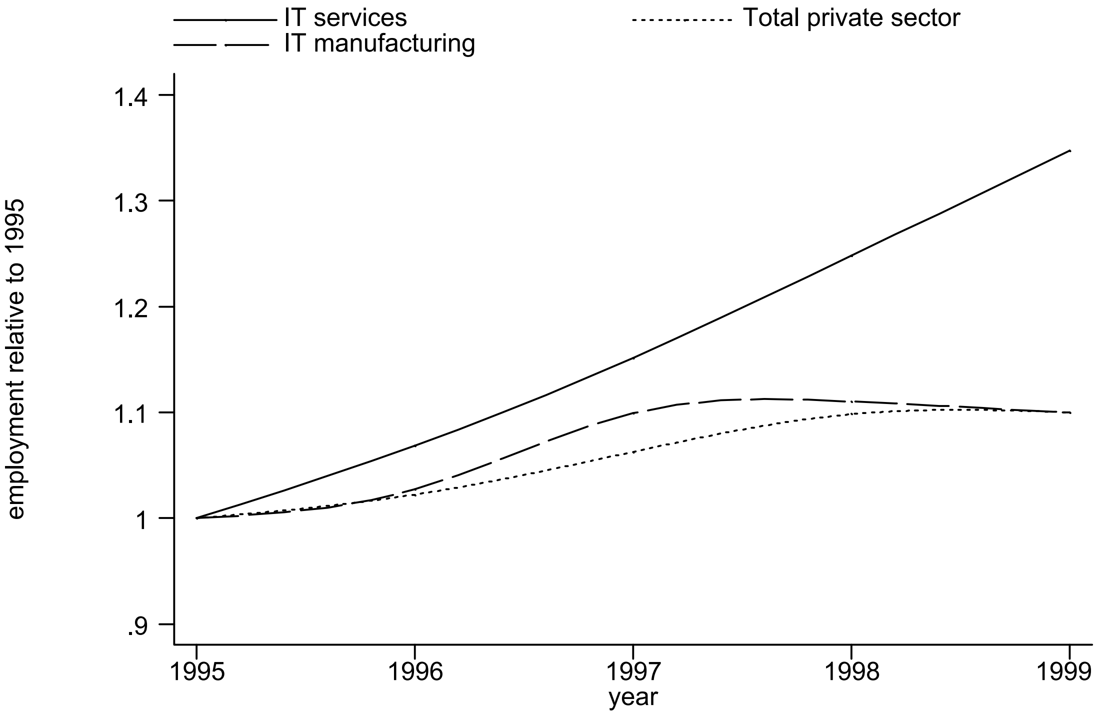
Source: Microdata from R&D surveys conducted by NTNF (The Royal Norwegian Council for Scientific and Industrial Research) and Statistics Norway. Annual data points are connected using a cubic spline. High-tech industries are defined as ISIC 382-385.

Figure 2: Employment growth 1985-1997 in subsidized IT R&D-firms vs. other cathegories of firms in the high-tech industry



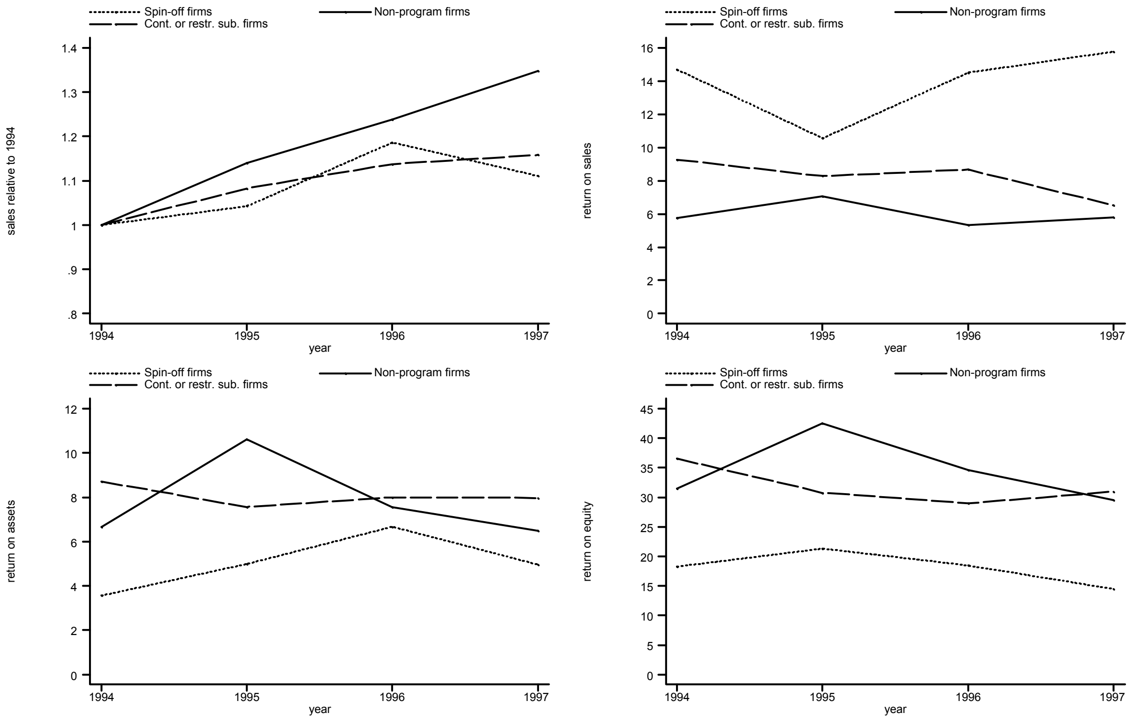
Subsidized IT R&D-firms are firms with an intensity of subsidized IT-related R&D above 0.005 and intensity of IT-related R&D above 0.1 in at least one of the years 1986-1990. Non-subsidized IT R&D-firms are less subsidized firms with an intensity of IT-related R&D above 0.1 in at least one of the years 1986-1990. Other R&D firms are other firms with R&D intensity above 0.1 in at least one of the years 1986-1990. In 1985 there were about 11 100 workers in subsidized IT R&D firms, 1 800 workers in non-subsidized IT R&D firms, 5 800 workers in other R&D firms and 58 600 workers in non-R&D firms. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. Firms with unknown R&D-intensity are excluded. High-tech industries are defined as ISIC 382-385. Firms that change industry classification are kept in the sample. Annual data points are connected using a cubic spline.

Figure 3: Employment growth in IT vs. all private industries in 1995-1999



Source: Statistics Denmark (2000) updated with numbers from Statistics Norway (www.ssb.no). IT-manufacturing is defined as production of computers and office machinery, production of insulated wires and cables, production of radio, TV and communication equipment, production of instruments except medical and surgical equipment (NACE 30, 313, 32, 332 and 333). The IT service sector comprises wholesaling, telecommunications and consultancy (NACE 51433, 5164, 51654, 642, 7133 and 72). The various IT sectors are defined as recommended by OECD, except for wholesaling which is slightly more targeted towards IT. See Statistics Denmark (2000) for details. Total private sector comprises NACE 15-37, 45, 50-74, 92 and 93. Annual data points are connected using a cubic spline.

Figure 4: Joint growth and profitability of spin-off firms vs. non-spin-off firms in 1994 to 1997



Source: Statistics Norway, Statistics of accounts for non-financial joint-stock companies. Both spin-off firms and continuing or reorganized subsidized firm are defined as having had at some point, at least a 25 percent share of employees with experience from subsidized IT R&D-firms, and at least one scientist or engineer with experience from subsidized IT R&D-firms. Together these two groups of firms constitute the 'program firms'. Spin-off firms are program firms that do not contain a plant that has been part of an originally subsidized firm. Continuing or reorganized subsidized firms are program firms that do contain a plant that has been part of an originally subsidized firm. The sample consists of all firms with more than one employee and at least one scientist or engineer, in industries with at least one program firm.

Table 1. Industry of occupation in 1997 for scientists and engineers with experience from high-tech industries in 1986-1990

	Workers from subsidized IT R&D firms	Workers from non-subsidized IT R&D firms	Workers from other R&D firms	Workers from non-R&D firms
High-tech manufacturing industries	40%	53%	49%	44%
Other manufacturing industries	2%	4%	3%	7%
IT services industries	30%	14%	10%	6%
Other services industries	12%	14%	15%	23%
Public sector	5%	5%	6%	4%
Other industries or unknown	2%	1%	8%	8%
Not in the sample	9%	9%	9%	7%
Number of scientists and engineers	1095	195	465	1664

The sample consists of male scientists and engineers born after 1935 with full time experience from a high-tech firm at least one of the years 1986-1990. High tech manufacturing industries are defined as NACE 29-35 (ISIC382-385). IT service industries are defined as NACE 51433, 5164, 51654, 642, 7133 and 72. R&D firms are firms with R&D-intensity above 0.1. IT R&D-firms are R&D firms with intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are IT R&D-firms with intensity of subsidized IT-related R&D above 0.005. Non-R&D firms are firms that have R&D intensity below 0.1. Workers are classified in the leftmost column applicable. Workers who are not observed in 1997 are classified according to their industry of occupation in 1996, if possible. Otherwise they are classified as not in the sample. R&D-intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. Workers that only have experience from firms with unknown R&D-intensity are excluded.

Table 2. Non-wage labor market outcomes for scientists and engineers with experience from high-tech industries in 1986-1990

	Workers from subsidized IT R&D firms	Workers from non-subsidized IT R&D firms	Workers from other R&D firms	Workers from non-R&D firms
Share of displaced workers that were re-employed in a different municipality‡	11%	11%	14%	14%
Participated in active labor market programs 1988-1997	13%	11%	11%	11%
Average employment rate 1988-1997	88%	87%	89%	89%
Re-educated or further educated by 1997	2.1%	2.1%	1.7%	1.7%
Self-employed in at least one year after 1990	.01%	.01%	.02%	.01%
Number of scientists and engineers	1095	195	465	1664

The sample consists of male scientists and engineers born after 1935 with full time experience from a high-tech firm at least one of the years 1986-1990. High tech manufacturing industries are defined as NACE 29-35 (ISIC382-385). R&D firms are firms with R&D-intensity above 0.1. IT R&D-firms are R&D firms with intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are IT R&D-firms with intensity of subsidized IT-related R&D above 0.005. Non-R&D firms are firms that have R&D intensity below 0.1. Workers are classified in the leftmost column applicable. R&D-intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. Workers that only have experience from firms with unknown R&D-intensity are excluded.

‡ A displaced worker is defined as a worker with at least two year tenure who left a plant that downsized at least 25 percent in that year or over that year and next year.

Table 3. The effect of R&D, IT and IT-subsidies on the *wage level* for scientists and engineers in high-tech industries in *1986-1990*

A: All observations	(1) Dummy	(2) Intensity	(3) Dummy	(4) Intensity
R&D	.007	.048	.005	.025
	(.009)	(.043)	(.009)	(.045)
IT R&D	-.043***	-.245**	.010	-.270***
	(.008)	(.061)	(.015)	(.065)
Subsidized IT R&D			-.040***	.229*
			(.014)	(.121)
Number of observations	11 386	11 386	11 386	11 386
R-squared	.50	.50	.51	.51
B: Without workers with experience from Norsk Data				
R&D	-.008	.022	-.009	.051
	(.009)	(.044)	(.009)	(.046)
IT R&D	-.015*	-.108*	.0002	-.013
	(.008)	(.063)	(.015)	(.067)
Subsidized IT R&D			-.019	-.488***
			(.015)	(.125)
R-squared	.50	.50	.50	.50
Number of observations	10 513	10 513	10 513	10 513

The dependent variable is ln (real annual earnings). The sample consists of male scientists and engineers born after 1935 working full time in a (manufacturing) high-tech industry. High-tech industries are defined as ISIC 382-385 (NACE 29-35). The baseline comparison group is workers with experience from non-R&D firms. Control variables included in the regression, but not reported are a quartic in experience, a quadratic in tenure, dummies for 15 different academic degrees, a quadratic in plant number of employees, dummies for 3 different regions, year dummies, 6 industry dummies and 3 dummies denoting whether the R&D, IT or subsidy variable is missing. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within individuals, are given in parentheses. In the dummy specifications, R&D firms are defined as firms with R&D intensity above 0.1. IT R&D-firms are defined as R&D-firms with an intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are defined as IT-firms with an intensity of subsidized IT-related R&D above 0.005. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms.

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

Table 4. The effect of R&D, IT and IT-subsidies on the *wage profile* for scientists and engineers in high-tech industries in *1986-1990*

A: All observations	(1) Dummy	(2) Intensity	(3) Dummy	(4) Intensity
R&D	.015	.081	.013	.016
	(.016)	(.074)	(.015)	(.075)
R&D * experience	-.001	-.004	-.001	.0001
	(.001)	(.005)	(.001)	(.005)
IT R&D	-.109***	-.600***	-.088***	-.696***
	(.015)	(.104)	(.023)	(.108)
IT R&D * experience	.006***	.031***	.007***	.037***
	(.001)	(.008)	(.002)	(.009)
Subsidized IT R&D			-.027	.837***
			(.022)	(.205)
Subsidized IT R&D * experience			-.001	-.051***
			(.002)	(.017)
R-squared	.51	.51	.51	.51
Number of observations	11 386	11 386	11 386	11 386
B: Without workers with experience from Norsk Data				
R&D	-.004	.057	-.005	.049
	(.015)	(.075)	(.015)	(.075)
R&D * experience	-.0004	-.004	-.0004	-.001
	(.001)	(.005)	(.001)	(.005)
IT R&D	-.064***	-.426***	-.070***	-.426***
	(.015)	(.109)	(.023)	(.113)
IT R&D * experience	.004***	.028***	.006***	.035***
	(.001)	(.008)	(.002)	(.009)
Subsidized IT R&D			.009	.138
			(.022)	(.211)
Subsidized IT R&D * experience			-.003	-.050***
			(.002)	(.017)
R-squared	.51	.51	.51	.51
Number of observations	10 513	10 513	10 513	10 513

The dependent variable is ln (real annual earnings). The sample consists of male scientists and engineers born after 1935 working full time in a high-tech industry. High-tech industries are defined as ISIC 382-385 (NACE 29-35). The baseline comparison group is workers with experience from non-R&D firms. Control variables included in the regression, but not reported are a quartic in experience, a quadratic in tenure, a dummy for job relationships whose starting date is censored at April 30th 1978 together with its interactions with the two tenure variables, dummies for 15 different academic degrees, a quadratic in plant number of employees, dummies for 3 different regions, year dummies, year dummies interacted with experience, 6 industry dummies, 3 dummies denoting whether the R&D, IT or subsidy variable is missing and these dummies interacted with experience. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within individuals, are given in parentheses. In the dummy specifications, R&D firms are defined as firms with R&D intensity above 0.1. IT R&D-firms are defined as R&D-firms with an intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are defined as IT-firms with an intensity of subsidized IT-related R&D above 0.005. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms.

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

Table 5. The effect of R&D, IT and IT-subsidies on *wage growth 1986-1997* for scientists and engineers in high-tech and IT industries

A: All observations	(1) Dummy	(2) Stock	(3) Dummy	(4) Stock
R&D-experience	-.017	-.005	-.018	.003
	(.018)	(.031)	(.018)	(.030)
IT R&D-experience	.042**	.069*	.003	.093**
	(.018)	(.038)	(.028)	(.042)
Subsidized IT R&D experience			.047*	-.155*
			(.025)	(.072)
R-squared	.23	.23	.23	.23
Number of observations	7 130	7 130	7 130	7 130
B: Without workers with experience from Norsk Data				
R&D-experience	-.010	.015	-.011	.010
	(.018)	(.031)	(.018)	(.030)
IT R&D-experience	.016	-.003	.011	-.008
	(.018)	(.039)	(.028)	(.034)
Subsidized IT R&D experience			.007	.045
			(.025)	(.077)
R-squared	.23	.23	.23	.23
Number of observations	6 762	6 762	6 762	6 762

The dependent variable is the first difference of ln (real annual earnings) between year *t* and year *t-10* in the period 1986 to 1997. The sample consists of male scientists and engineers born after 1935, having some full time experience in at least one of the years 1986-1990 and having full time experience in a high-tech or IT industry in at least one of the years 1986-1997. High-tech and IT industries are defined as NACE 29-35, 51433, 5164, 51654, 642, 7133 and 72. The latter six are IT service industries. The baseline comparison group is workers with experience from non-R&D manufacturing high-tech firms. Control variables included in the regression, but not reported are a quartic in experience a quadratic in tenure, a dummy for job relationships whose starting date is censored at April 30th 1978 together with its interactions with the two tenure variables, year dummies and dummies for 15 different academic degrees, a dummy for having experience from IT service, but not from high-tech manufacturing in 1986-1990, a dummy for not having experience from high-tech manufacturing, nor from IT service in 1986-1990, a dummy for being displaced in one of the years 1986 to 1993, 28 dummies for industry of occupation at time *t*, 28 dummies for industry of occupation at time *t-10,* two dummies denoting whether R&D or IT R&D is missing for those with experience from manufacturing firms and a similar dummy for subsidized IT R&D in column 4. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within individuals, are given in parentheses. In columns 1, and 3, R&D experience is measured as having experience from a firm with R&D intensity above 0.1. Likewise, IT R&D experience is measured as having experience from a firm with intensity of IT R&D above 0.1, and subsidized IT R&D experience is measured as having experience from a firm with intensity of subsidized IT R&D above 0.005. In columns 2, and 4, R&D experience is measured as the sum of the employers' R&D intensities over the years 1986-91. Likewise, IT R&D experience is measured as the sum of the employers' intensities in IT-related R&D and subsidized IT R&D experience is measured as the sum of the employers' intensities in subsidized IT-related R&D. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. R&D information is only available for manufacturing firms.

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

Table 6. The effect of R&D, IT and IT-subsidies in 1986-1990 on the *wage level* for scientists and engineers in *1996 and 1997* in high-tech and IT industries

A: All observations	(1) Dummy	(2) Stock	(3) Dummy	(4) Stock
R&D-experience	.012	.035	.012	.037
	(.017)	(.027)	(.017)	(.036)
IT R&D-experience	-.007	-.021	.004	-.014
	(.017)	(.035)	(.026)	(.038)
Subsidized IT R&D experience			-.012	-.041
			(.024)	(.082)
R-squared	.21	.21	.21	.21
Number of observations	10 109	10 109	10 109	10 109
B: Without workers with experience from Norsk Data				
R&D-experience	.011	.031	.011	.033
	(.017)	(.027)	(.017)	(.027)
IT R&D-experience	-.003	-.009	.005	.004
	(.017)	(.036)	(.026)	(.043)
Subsidized IT R&D experience			-.009	-.059
			(.025)	(.093)
R-squared	.22	.22	.22	.22
Number of observations	9 632	9 632	9 632	9 632

The dependent variable is ln (real annual earnings). The sample consists of male scientists and engineers born after 1935, having some full time experience in at least one of the years 1986-1990 and having full time experience in a high-tech or IT industry in at least one of the years 1986-1997. High-tech and IT industries are defined as NACE 29-35, 51433, 5164, 51654, 642, 7133 and 72. The latter six are IT service industries. The baseline comparison group is workers with experience from non-R&D (manufacturing) high-tech firms. Control variables included in the regressions, but not reported are a quartic in experience, a quadratic in tenure, a dummy for job relationships whose starting date is censored at April 30th 1978 together with its interactions with the two tenure variables, year dummies and dummies for 15 different academic degrees, a quadratic in plant number of employees, a dummy for being displaced in one of the years 1986 to 1993, dummies for 3 different regions, a dummy for having experience from IT service, but not from high-tech manufacturing in 1986-1990, a dummy for not having experience from high-tech manufacturing, nor from IT service in 1986-1990, 28 industry dummies, two dummies denoting whether R&D or IT R&D is missing for those with experience from manufacturing firms and a similar dummy for subsidized IT R&D in column 4. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within individuals, are given in parentheses. In columns 1, and 3, R&D experience is measured as having experience from a firm with R&D intensity above 0.1. Likewise, IT R&D experience is measured as having experience from a firm with intensity of IT R&D above 0.1, and subsidized IT R&D experience is measured as having experience from a firm with intensity of subsidized IT R&D above 0.005. In columns 2, and 4, R&D experience is measured as the sum of the employers' R&D intensities over the years 1986-91. Likewise, IT R&D experience is measured as the sum of the employers' intensities in IT-related R&D and subsidized IT R&D experience is measured as the sum of the employers' intensities in subsidized IT-related R&D. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. R&D information is only available for manufacturing firms.

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

Table 7: Growth in 1994-1997 in firms that employ knowledge developed in the subsidized IT R&D firms

	(1)	(2)
Dummy for program firm	.064	
	(.044)	
Dummy for continuing or reorganized subsidized firm		.075
		(.086)
Dummy for spin-off firm		.060
		(.045)
R-squared	.93	.93
Number of observations	3 641	3 641

The dependent variable is ln(Sales). The sample consists of annual observations all firms with more than one employee and at least one scientist or engineer, in industries with at least one program firm. A program firm is defined as having had, at some point, at least a 25 percent share of employees with experience from subsidized IT R&D-firms, and at least one scientist or engineer with experience from subsidized IT R&D-firms. A spin-off firm is defined as a program firm that does not contain a plant that has been part of an originally subsidized firm. A continuing or reorganized subsidized firm is defined as a program firm that does contain a plant that has been part of an originally subsidized firm. Control variables included in the regression, but not reported are ln($Sales_{t-1}$), a quartic in firm age, a quartic in firm no. of employees, a quartic in the share of employees that are scientists and engineers, a dummy for positive R&D-investments, a dummy for R&D-intensity above 0.05, a dummy for R&D-intensity above 0.2, a dummy for no information about R&D investments, year dummies and 38 NACE industry dummies. Firm age is deliberately censored at 30 and firm no. of employees is censored at 1000. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within firms, are given in parentheses. The influence of outliers is reduced by replacing values for return on sales, assets and equity below the 5^{th} percentile with the 5^{th} percentile, and values above the 95^{th} percentile with the 95^{th} percentile.

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

Table 8: Profitability in 1994-1998 in firms that employ knowledge developed in the subsidized IT R&D firms

A: Return on sales	(1)	(2)
Dummy for program firm	-1.22	
	(1.00)	
Dummy for continuing or reorganized subsidized firm		1.57
		(1.48)
Dummy for spin-off firm		-2.56**
		(1.24)
R-squared	.08	.08
B: Return on assets		
Dummy for program firm	-3.15*	
	(1.67)	
Dummy for continuing or reorganized subsidized firm		1.25
		(2.51)
Dummy for spin-off firm		-5.26***
		(2.00)
R-squared	.07	.08
C: Return on equity		
Dummy for program firm	-15.51**	
	(7.57)	
Dummy for continuing or reorganized subsidized firm		2.57
		(11.79)
Dummy for spin-off firm		-24.19***
		(8.68)
R-squared	.06	.06
Number of observations	3 719	3 719

The sample consists of annual observations all firms with more than one employee and at least one scientist or engineer, in industries with at least one program firm. A program firm is defined as having had, at some point, at least a 25 percent share of employees with experience from subsidized IT R&D-firms, and at least one scientist or engineer with experience from subsidized IT R&D-firms. A spin-off firm is defined as a program firm that does not contain a plant that has been part of an originally subsidized firm. A continuing or reorganized subsidized firm is defined as a program firm that does contain a plant that has been part of an originally subsidized firm. Control variables included in the regression, but not reported are a quartic in firm age, a quartic in firm no. of employees, a quartic in the share of employees that are scientists and engineers, a dummy for positive R&D-investments, a dummy for R&D-intensity above 0.05, a dummy for R&D-intensity above 0.2, a dummy for no information about R&D investments, year dummies and 38 NACE industry dummies. Firm age is deliberately censored at 30 and firm no. of employees is censored at 1000. The coefficients are estimated using ordinary least squares. Standard errors, adjusted for heteroscedasticity and correlated error terms within firms, are given in parentheses. The influence of outliers is reduced by replacing values for return on sales, assets and equity below the 5^{th} percentile with the 5^{th} percentile, and values above the 95^{th} percentile with the 95^{th} percentile.

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

Table A1. Worker-year observations of scientists and engineers in high-tech industries by ISIC sub-industry and firm type in 1986-1990

		Sub. IT R&D firms	Non-sub. IT R&D firms	Other R&D firms	Non-R&D firms	Firms with un-known R&D	Firms' IT R&D-intensity weighted by no. of obs.
38210	Engines and turbines	0	0	0	351	1	.0004
38220	Agricultural machinery	0	0	1	69	4	.0011
38230	Metal and wood-working machinery	0	0	0	5	0	.0000
38241	Oil and gas well machinery and tools	0	0	0	1 748	106	.0005
32249	Other industrial machinery	0	0	0	132	21	.0004
38250	Computers and office machinery	938	386	17	15	133	.1970
38291	Household machinery	0	0	0	17	17	.0000
38292	Repair of machinery	0	0	2	35	74	.0000
38299	Other machinery	327	30	233	767	190	.0441
38310	Electric motors and eq. for el. production	10	25	316	381	160	.0253
38320	Radio, TV and communication apparatus	1 123	145	660	790	421	.1262
38330	Electrical household appliances	0	0	25	14	1	.0513
38391	Insulated cables and wires	272	0	158	54	24	.1311
38399	Other electrical apparatus and equipment	7	15	5	87	42	.0852
38411	Building of ships	0	0	0	216	135	.0002
38412	Building of boats	0	0	0	19	17	.0000
38413	Ship and boat engines and motors	0	0	0	102	12	.0004
38414	Components and fixtures for ships/boats	0	0	13	102	17	.0006
38421	Railway and tramway equipment	0	0	0	29	0	.0000
38422	Repair of railway and tramway eq.	0	0	0	60	0	.0000
38430	Motor vehicles	19	0	5	102	54	.0804
38440	Motor cycles and bicycles	0	0	0	18	0	.0050
38450	Aircraft	0	0	0	128	0	.0006
38490	Other transport equipment	0	0	0	1	0	.0000
38510	Professional and scientific instruments	81	28	101	119	96	.1311
38520	Photographic and optical goods	34	17	11	0	0	.1580
382-385	All machinery and equipment industries	2 811	646	1 546	5 361	1 525	.0810

The sample consists of male scientists and engineers born after 1935 working full time in a high-tech industry (ISIC 382-385) in 1986-1990. R&D firms are defined as firms with R&D intensity above 0.1. IT R&D-firms are defined as R&D-firms with an intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are defined as IT-firms with an intensity of subsidized IT-related R&D above 0.005. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms.

Table A2. Characteristics of scientists and engineers by firm type in high-tech industries

	Workers from subsidized IT R&D firms	Workers from non-subsidized IT R&D firms	Workers from other R&D firms	Workers from non-R&D firms
Year of birth (average)	1953	1954	1953	1953
Years of tenure (average) ‡	3.3	2.6	3.3	3.0
Years of education (average)	16.8	16.7	16.7	16.6
Wage in 1995 NOK (average)	350’	347’	377’	352’
Union membership (share in 1991)	16%	13%	13%	18%
Rural residence (share)	6%	6%	10%	16%
Foreign born (share)	6%	4%	6%	7%
Employers’ average R&D intensity	.19	.17	.13	.03
Employers’ average intensity of IT R&D	.16	.16	.03	.01
Employers’ average intensity of subsidized IT R&D	.036	.001	.006	.001
Obs. with R&D info. per worker 1986-91 (average) ‡‡	3.8	3.4	2.7	3.0
Obs. per worker 1986-1990 (average) ‡‡	4.7	4.7	4.7	4.7
Experience from Norsk Data (share)	26%	0%	0%	0%
Number of scientists and engineers	1 095	195	465	1 664

The sample consists of male scientists and engineers born after 1935 with full time experience from a high-tech firm (ISIC 382-385) at least one of the years 1986-1990. The statistics is based on the first observation of each worker. Workers in firms with unknown R&D-intensity are excluded. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms. ‘Rural residence’ implies that the worker lives in a municipality where firms have some sort of preferential tax treatment.

‡ 8 percent of the observations have job starting date censored at April 30th 1978.

‡‡ Only workers who finished their education before 1986 and who were still employed after 1990 are included.

Table A3. Educational composition by firm type in high-tech industries in 1986-1990

	Sub. IT R&D firms	Non-sub. IT R&D firms	Other R&D firms	Non-R&D firms	*Total no. of obs.*
Total number of worker-year observations	18 170	4 296	15 114	173 756	211 336
Scientists and engineers	15%	15%	10%	3%	10 364
College degree in technology	22%	18%	17%	7%	19 616
Secondary technical education	24%	27%	33%	46%	90 985
Higher general or administrative education	11%	9%	6%	3%	8 731
Secondary general or administrative education	18%	21%	19%	18%	38 685
Unskilled	8%	9%	14%	21%	40 193
Unknown education	2%	1%	1%	1%	2 762
	100%	100%	100%	100%	
Scientists and engineers	2 811	646	1 546	5 361	10 364
PhD Engineering	1%	1%	1%	2%	150
MSc Engineering Electrotechnics/Computers	45%	56%	53%	17%	3371
BSc Electrotechnical Engineering	15%	12%	13%	9%	1204
PhD Mathematics and natural science	2%	2%	1%	1%	143
MSc Mathematics	6%	4%	2%	1%	287
MSc Physics	5%	4%	2%	1%	297
MSc Engineering Machinery	6%	5%	9%	32%	2065
BSc Mechanical Engineering	1%	2%	2%	12%	710
MSc Engineering Architecture and Construction	.1%	0%	.5%	7%	375
MSc Engineering Chemistry and Geology	1%	.5%	1%	2%	174
MSc Chemistry and Geology	1%	1%	.5%	.2%	48
MSc Life Sciences	1%	0%	1%	1%	102
MSc Natural Sciences, unspecified	4%	4%	6%	5%	476
MSc Other engineering	9%	9%	7%	7%	799
BSc Other Engineering	1%	.2%	1%	3%	181
	100%	100%	100%	100%	

The sample consists of male scientists and engineers born between 1935 and 1975 with full time experience from a high-tech firm (ISIC 382-385) at least one of the years 1986-1990. Workers in firms with unknown R&D-intensity are excluded. R&D firms are defined as firms with R&D intensity above 0.1. IT R&D-firms are defined as R&D-firms with an intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are defined as IT-firms with an intensity of subsidized IT-related R&D above 0.005. R&D intensity is measured as R&D man-years per employee at the three-digit line of business level within firms.

Table A4. Plant characteristics by firm type in high-tech industries in 1986-1990

	Subsidized IT R&D firms	Non-subsidized IT R&D firms	Other R&D firms	Non-R&D firms
Average number of employees	133	80	86	73
Average experience	16	16	16	18
Average tenure‡	4.8	4.3	4.6	5.1
Average education	12.9	13.1	12.0	10.8
Average share of work force with higher technical or scientific education	.072	.070	.057	.009
Average hourly wage in 1995 NOK	176	183	180	165
Average capital per employee in 1995 NOK	772’	798’	1085’	748’
Average R&D man-years per employee	.28	.27	.21	.01
Average share of R&D that is IT-related	.89	.91	.18	.04
Average IT R&D man-years per employee	.24	.24	.03	.002
Average share of total R&D that is subsidized	.19	.002	.15	.06
Average subs. IT R&D man-years per employee	.045	.0004	.008	.0002
Average market share	.063	.038	.028	.030
Average union density (1991)	.42	.20	.32	.52
Plants with rural location (share)	.25	.14	.25	.31
Share of work force that is foreign born	.05	.05	.04	.04
Part of multi-plant firm (share)	.61	.47	.45	.44
Part of foreign owned firm (share)	.37	.14	.22	.08
Plants founded before 1966 (share)	.15	.25	.27	.39
Annual growth rate in 1983-1986‡‡	.34	.19	.18	.19
Plant closed before 1994 (share)	.46	.31	.33	.20
Number of plant-year observations	233	101	295	4 079
Number of plants	79	29	89	976
Number of firms	52	27	65	813

The statistics are based on all plant-year observations in ISIC 382-385 in 1986-1990. R&D firms are defined as firms with R&D intensity above 0.1. IT R&D-firms are defined as R&D-firms with an intensity of IT-related R&D above 0.1. Subsidized IT R&D-firms are defined as IT-firms with an intensity of subsidized IT-related R&D above 0.005. R&D man-years per employee is measured at the three-digit line of business level within firms. Firms with unknown R&D-intensity are excluded. Market share relates to national production and is measured at the five-digit line of business level for the firm that the plant belongs to. Rural location implies that the firm is located in a municipality where firms have some sort of preferential tax treatment. Multi-plant firms are only counted once in each industry-year when computing the market share statistics. A foreign owned firm is a firm that has more than 50 percent foreign ownership. The number of firms and plants refer to the number of unique firm and plant identifiers over the years 1986-1990, and are classified according to the leftmost column applicable.

‡ 18 percent of the underlying employee observations have the job starting date censored at April 30th 1978.

‡‡ The reported growth rates are the median within each group. Growth refers to growth in nominal sales.

Table A5. Characteristics of 'program firms' and spin-offs

	Non-program firms	Program firms	Program firms that are cont. or reorganized subsidized firms	Program firms that are spin-offs
Average number of employees	116	176	253	129
Median number of employees	21	24	60	8
Average capital per employee	1 416'	3 486'	879'	5 056'
Median capital per employee	551'	657'	769'	533'
Average number of plants per firm	1.6	2.4	1.9	2.7
Average R&D man-years per employee	.04	.13	.15	.10
Average share of scientists and engineers in the work force	.16	.30	.17	.38
Average share of equity in total assets	.31	.36	.35	.37
Average ownership share of the largest foreign owner	.20	.20	.18	.20
Share of firms with rural location	.14	.03	.00	.05
Share of firms founded before 1986	.41	.31	.60	.15
Share of firms founded before 1991	.75	.65	.96	.46
Share of firms classified as belonging to a high-tech or IT-industry	.56	.78	1.00	.65
Share of firms classified as belonging to an IT-service industry	.36	.34	.15	.46
Share of firms rooted in Norsk Data	0	.24	.03	.37
Number of firm-year observations	3 643	274	103	171
Number of firms	1 437	109	33	76

The statistics are based on all firm-year observations in 1994-1998. The sample consists of all firms with more than one employee and at least one scientist or engineer, in industries with at least one program firm. A program firm is defined as having had, at some point, at least a 25 percent share of employees with experience from subsidized IT R&D-firms, and at least one scientist or engineer with experience from subsidized IT R&D-firms. A spin-off firm is defined as a program firm that does not contain a plant that has been part of an originally subsidized firm. Firms that are 'rooted' in Norsk Data are defined as having had, at some point, at least a 25 percent share of employees with experience from Norsk Data, and at least one scientist or engineer with experience from Norsk Data. Capital is measured in nominal NOK. Rural location implies that the firm is located in a municipality where firms have some sort of preferential tax treatment. High-tech and IT industries comprise NACE 29-35, 51433, 5164, 51654, 642, 7133 and 72.