

Labor Demand Effect of Public R&D Funding

Bernd Ebersberger
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VTT, Vuorimiehentie 5, PL 2000, 02044 VTT
puh. vaihde (09) 4561, faksi (09) 456 4374

VTT, Bergsmansvägen 5, PB 2000, 02044 VTT
tel. växel (09) 4561, fax (09) 456 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 5, P.O.Box 2000, FIN-02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 4374

VTT Teknologian tutkimus, Kemistintie 3, PL 1002, 02044 VTT
puh. vaihde (09) 4561, faksi (09) 456 7007

VTT Teknologistudier, Kemistvägen 3, PB 1002, 02044 VTT
tel. växel (09) 4561, fax (09) 456 7007

VTT Technology Studies, Kemistintie 3, P.O.Box 1002, FIN-02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 7007

Author(s) Ebersberger, Bernd		
Title Labor Demand Effect of Public R&D Funding		
Abstract <p>This paper analyzes the employment effects of publicly subsidized R&D. The basic, very stylized line of reasoning underlying this question is that public subsidies for R&D foster innovation; innovation, in turn, causes firm growth, which, in turn, also increases the firms' labor demand.</p> <p>The nexus of publicly subsidized R&D and the labor demand effect is usually treated in two distinct steps. The first step studies the direct output of the research activity and asks whether publicly subsidized R&D programs increase the companies' rate of innovation. The second step derives how the outcomes of the research activity (innovations, patents, etc.) influence the firms' labor demand. In this research we merge both steps. We directly analyze whether companies that received public subsidies show a differential labor demand subsequent to being subsidized.</p> <p>We test the hypothesis using data on a panel of Finnish firms consisting of subsidized as well as of not subsidized firms. To eliminate the selection bias and to estimate the impact of the subsidies we use a kernel-based matching and a diffs-in-diffs estimation.</p> <p>The results of this study support the hypothesis that public subsidies have a positive impact on companies' innovative output. They also establish an empirical link between the funding and the companies' subsequent labor demand. Public subsidies for innovation are found to have a positive influence on the companies' employment.</p>		
Keywords R&D subsidies, labor demand, evaluation, treatment effect, conditional difference in difference		
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1. Introduction

This study focuses on the question of whether public R&D subsidies have a positive impact on the labor demand of the subsidized firms. The basic, very stylized rationale giving rise to this question builds on the fact that public subsidies for R&D intend to foster innovation; innovation, in turn, causes firm growth, which also increases the subsidized firms' labor demand.¹

This line of reasoning can be decomposed into two distinct steps. The first step establishes the link between public subsidies and increased innovativeness. The microeconomic theory explains state intervention in the innovation process by the gap between the social and the private returns caused by market failure. The gap leads to a suboptimal level of R&D activities; the gap itself being caused by the public good nature of the results of R&D, causing only partial appropriability of the returns of the R&D investment (Arrow, 1962). Economies of scale and scope in R&D, as well as the high costs and the true uncertainty in the results of R&D, are other reasons for the underinvestment. Market failure in the context of R&D is also attributable to the asymmetry of information. Government intervention targets the underinvestment in R&D in two ways. First, direct subsidies target the underinvestment directly. The complementarity of public and private funding causes the overall investment to increase more than the share of public funding. Second, incentives to collaborate focus on the causes for the gap between social and private returns (D'Aspremont & Jaquemin, 1988, Kamien, Muller, & Zang, 1992, Miyagiwa & Ohno, 2002). The benefits from collaboration are associated with the increasing scale and scope of the activities, as well as the sharing of cost and risks. Collaboration also results in the companies' improved ability to handle complex innovations by different partners endowed with complementary assets (Dodgson, 1994). The latter beneficial effect of such collaboration is not so much due to underinvestment in R&D; rather, it relates to the R&D process directly improving innovativeness. If direct subsidies are designed to encourage firms to engage in research collaboration, both ways of remedying the market failure and increasing innovativeness can be implemented simultaneously. The overall rationale for public subsidies for R&D is summarized in Hypothesis 1.

Hypothesis 1: Public subsidies have a positive impact on the generation of innovative output.

Recent empirical studies have focused on the impact of public subsidies on the generation of innovative output, as in Hypothesis 1 (Almus & Czarnitzki, 2003, Branstetter & Sakakibara, 2002, Czarnitzky & Fier, 2003).

¹The discussion here does not include spillover effects that may occur for units other than the subsidized ones.

The second step in the rationale relating public R&D subsidies and the subsidized firms' labor demand focuses on the nexus between innovation and labor demand. In the discussion about the influence of innovation on the firms' labor demand one has to differentiate between two types of innovations: product innovations and process innovations. Based on the contributions by Katsoulakos, product innovations have a positive impact on the labor demand (Katsoulakos, 1986, Katsoulakos, 1984). Process innovations are characterized by an initial displacement effect, which reduces the labor demand. The reduced labor demand may only be a temporary phenomenon as various compensation mechanisms can even overcompensate the initial loss of employment to yield a positive effect in the long run. The discussion about the displacement of labor and the compensating forces is about as old as economics is as a science. See, for example, a good summary of the forces in Vivarelli and in Petit (Petit, 1995, Vivarelli, 1995).

Hypothesis 2: Innovations have a positive employment effect.

Various analyses on the micro level support a positive effect of innovations on the labor demand and find a positive net employment effect in different samples of German manufacturing firms (Entorf & Pohlmeier, 1990, Rottmann & Ruschinski, 1998, Smolny, 1998). For a sample of UK firms, Van Reenen finds a positive net impact of innovations, as the positive effect of product innovations exceeds the negative effect of process innovations (Van Renen, 1997). Blanchflower and Burgess also support the hypothesis about a positive employment effect for a sample of UK and Australian firms (Blanchflower & Burgess, 1998). Positive effects of innovation on the labor demand of the innovating firms are also found for a sample of Italian manufacturing firms (Piva & Vivarelli, 2002). However, the empirical evidence concerning Hypothesis 2 is not unanimous. A negative relationship between innovation and labor demand is found for a sample of Dutch firms (Brouwer, Kleinknecht, & Reijnen, 1993). A study of Norwegian plants reveals no clear positive relationship between innovation and the employment of the plants (Klette & Førre, 1998). An analysis on the industry level for a set of several European countries shows a negative net impact of product innovations and process innovations on employment (Antonucci & Pianta, 2002).

The key focus of this analysis is the combination of Hypothesis 1 and Hypothesis 2. It poses a direct link between the public subsidies for R&D and the labor demand of the subsidized firms. Of course, public subsidies, if they enable the companies to carry out large enough projects, will have a direct positive employment effect due to the companies' need to staff the projects. The employment effect we are alluding to here is beyond that, both in terms of time scale and scope. The employment effect relates to the project output in terms of innovation outcome rather than to the project inputs.

Hypothesis 3: Public subsidies have a significant employment effect.

Analysis relating public intervention to the innovation outcome in terms of firm growth and productivity growth can be found in various studies (Almus & Prantl, 2002, Branstetter & Sakakibara, 1998, Griliches & Regev, 1998, Irwin & Klenow, 1996, Klette, Møen, & Griliches, 2000, Lerner, 1996). With exception of the study by Klette and Møen, all studies find a positive impact of public intervention on the outcome variable under inspection. Yet only two studies investigate the link between public funding and labor demand (Almus & Prantl, 2002, Lerner, 1996). Lerner analyzes the employment impact of the US small business innovation research program (SBIR) designed to stimulate innovation in small high-tech companies. He shows that subsidized firms grow at a significantly higher rate than non-subsidized firms. Almus and Prantl find a strong positive effect of public funding on the survival probability and growth of young German firms. On the plant as well as on the firm level, Maliranta shows that subsidized units contributed more to the net employment growth than non-funded units (Maliranta, 2000).

The analysis in this paper finally aims at the link between public R&D subsidies and innovation output as in Hypothesis 1, and the relationship between R&D subsidies and the labor demand of subsidized firms as in Hypothesis 3. As Hypothesis 2 does not directly relate to R&D subsidies it will not be considered in the analysis in this paper, which unfolds as follows. In Section 2 we introduce the institutional background of the analyzed subsidies. Section 3 starts with sketching the methodological aspects of the evaluation and eventually introduces kernel-based matching as the empirical methodology used here. In Section 4 we describe the data sources and the construction of the data sets, and Section 5 contains the empirical analysis. The results relating to Hypothesis 1 are reported in Section 5.2.1 and Section 5.2.2 then elaborates on Hypothesis 3, the impact of the public subsidy on the subsidized companies' labor demand. Section 6 concludes.

2. Institutional background of the public R&D subsidies

In the analysis we focus on subsidy programs carried out by the Finnish National Technology Agency (Tekes).² The National Technology Agency has a prominent role in the Finnish national system of innovation (NSI). The two most relevant ministries in the Finnish NSI are the Ministry of Education and the Ministry of Trade and Industry. The division of labor among both is such that the universities and the Academy of Finland belong to the administrative field of the Ministry of Education. The Academy of Finland is the central body for planning and financing basic research. The National Technology Agency, however, belongs to the administrative field of the Ministry of Trade and Industry and is the central body for planning and financing applied research and development. In 2000 Tekes' financial resources amounted to 0.4 billion euro, which is about 30% of the total government outlay on R&D (Tekes, 2000).

Even though it might be argued that public intervention in R&D does not intend to stimulate economic growth (Georghiou & Roessner, 2000), it is the legal mission of the National Technology Agency (Tekes) to promote societal welfare by means of financing the development and utilization of technology. This is laid down in the Act on the National Technology Agency 429/1993:

[The aim of the National Technology Agency is] ... to promote the societal welfare and stable development by improving directly or indirectly the technological evolution and competence of industry to enhance its ability to develop internationally competitive products, processes and services ... The National Technology Agency plans, finances, and administers R&D projects that promote the development and utilization of technology. It funds and consults in ventures aimed at the development of products, processes and services as well as promotes widespread utilization of international technological know-how and cooperation, and technology transfer. In addition, Tekes takes part in the planning of Finnish technology and innovation policies along the lines given by the [Ministry of Trade and Industry]. (Section 2 and 3 of the Act on the National Technology Agency 429/1993 translation is taken from Väänänen and Hyytinen (Väänänen & Hyytinen, 2002).)

²In the following discussion we use the term 'program' as a synonym for any subsidizing activity carried out by Tekes. Hence any firm receiving subsidies for R&D activities participates in a program. *Program* here does not relate to Tekes' internal notion of programs that summarize any activity to promote development in specific sectors of technology or industry. We use the terms 'program participation' and 'receiving of subsidies' synonymously.

In operationalizing the legal mission Tekes regards employment growth as a final target of its R&D funding (Tekes 2003). Hence we can assume that Hypotheses 1 and 3 are in accordance with the targets of the Finnish National Technology Agency and the impact of the R&D subsidies can be studied on the basis of these hypotheses.

3. Methodology

Klette et al. note that "evaluating large-scale subsidy programs is an exercise in counterfactual analysis" (Klette, Møen, & Griliches, 2000). What this means and how we are analyzing the counterfactual in this study will be discussed in the following sections.

3.1 The evaluation problem

To illustrate the evaluation problem, imagine that a firm, i , can take two states, which are denoted 0 and 1. State 1 is associated with the company having undergone a certain treatment, whereas state 0 can be considered the state in which the company has not received the treatment. The treatment in our case is receiving public subsidies. The result of the company's activities in state 0 is denoted π_{i0} and the result in the state of 1 is denoted π_{i1} .

The impact of the treatment the firm receives can be given by equation (1), where Δ_i is called the *effect of the treatment on the treated* if company i actually received subsidies.

$$\Delta_i = \pi_{i1} - \pi_{i0} \tag{1}$$

The evaluation problem would not exist if we could observe π_{i0} and π_{i1} at the same time. In other words, evaluation of the public subsidy program would be a trivial task if we could observe the outcome of a company's activities being subsidized and not being subsidized at the same time. Unfortunately, though, in the social sciences we are confronted with missing data as we cannot observe π_{i1} and π_{i0} simultaneously. For the subsidized companies we only observe π_{i1} . We do not observe π_{i0} , which is the counterfactual; it describes what would have been the situation of company i had it not received the subsidy. Hence the evaluation problem is a missing data problem, a solution to which can be found by estimating the missing data. The estimation, however, has to control for the selection bias that arises due to the fact that receiving a subsidy cannot be thought of as being a purely random event.

In this study we use a matching approach to estimate the counterfactual. The basic idea in this approach is to overcome the evaluation problem by estimating the counterfactual based on the *conditional independence assumption*. This assumption states that, as long as the subsidized and the not subsidized firms share the same characteristics, the counterfactual state of the subsidized companies can be estimated by the observed state of the not subsidized companies (Rosenbaum & Rubin, 1983, Rubin, 1979). Once both the population of subsidized and the population of not subsidized companies share the same characteristics the selection bias is eliminated (Blundell & Costa Dias, 2000).

This conditional independence assumption implies that the counterfactual π_{i0} of a subsidized firm, i , can be approximated by estimating π_{k0} of a not subsidized company, k , that is similar to company i . Similarity here means that the characteristics \mathbf{x}_k of company k are similar to the characteristics \mathbf{x}_i of company i . Hence we match a non-participating company, k , to the participating company, i , based on the observed characteristics \mathbf{x}_k and \mathbf{x}_i . To simplify the notation and to stress the pair-wise nature of the matching result, we use \mathbf{x}_i and π_i for the participating company and $\mathbf{x}_{\tilde{i}}$ and $\pi_{\tilde{i}}$ for the matched, non-participating company.

The mean estimated effect - $\text{mean}(\tilde{\Delta}_i)$ - can then be computed from the means of the participating and the not participating companies, as in (2).

$$\text{mean}(\tilde{\Delta}_i) = \text{mean}(\pi_i) - \text{mean}(\pi_{\tilde{i}}) \quad (2)$$

Various methods can be used to identify a matching company - i.e. to construct the counterfactual. An extensive overview of those approaches can be found in Heckman et al., who discuss the evaluation of active labor market programs (Heckman, Lalonde, & Smith, 1999).

In this study we use a kernel-based matching suggested by Heckman and collaborators (Heckman, Ichimura, & Todd, 1997a, Heckman, Ichimura, & Todd, 1997b). Czarnitzki and Fier use kernel-based matching in a set-up comparable to the one presented here.

3.2 Kernel-based matching

Kernel-based matching estimates the counterfactual with a convex combination of all not subsidized companies.

$$\tilde{\pi}_i = \sum_{j \in I_0} \lambda_{ij} \pi_j \quad \text{with} \quad \sum_{j \in I_0} \lambda_{ij} = 1 \quad \text{and} \quad i \in I_1 \quad (3)$$

$I_{1(0)}$ is the set of indices of the (not) subsidized companies. To determine the weights λ_{ij} a kernel function, $K(\cdot)$, is used.

$$\lambda_{ij} = \frac{K(d_{ij})/h}{\sum_{k \in I_0} K(d_{ik})/h} \quad i \in I_1; j \in I_0 \quad (4)$$

The kernel attaches a higher weight to company j the closer it is to company i . In (4) d_{ij} gives the distance between company i characterized by \mathbf{x}_i and company j characterized by \mathbf{x}_j .

The distance in the multi-dimensional space of firm characteristics is measured by the Mahalanobis metric

$$d_{ij} = (\mathbf{x}_i - \mathbf{x}_j)' \Omega^{-1} (\mathbf{x}_i - \mathbf{x}_j) \quad (5)$$

where Ω^{-1} is the inverted covariance matrix of the matrix \mathbf{X}_0 containing all vectors \mathbf{x}_j with $j \in I_0$. In our analysis we use the Gaussian kernel given in (6).

$$K(d_{ij}) = (2\pi)^{-0.5} e^{-0.5(d_{ij}/h)^2} \quad (6)$$

where h is the bandwidth. Following Bergemann et al. we define h as

$$h = k(0.9n^{-0.2})^2 \quad (7)$$

where n_v and n_0 are the dimensions of \mathbf{X}_0 (Bergemann, Fitzenberger, & Speckesser, 2001). We use the factor $\delta=0.5$ to scale the bandwidth.

4. Data

For the analysis contained in this paper, we draw on various data sources.

4.1 Publicly subsidized R&D projects

The National Technology Agency supplied a list of companies that have received research grants. The information included the starting year of the funded research project as well as the termination year of the project.³ After sifting and removing companies due to lack of common support with the group of non-subsidized companies, we analyzed 1,894 companies being funded for 2,750 projects commencing in 1994 or later.

Table 1: Duration of the funded projects

1 year	2 years	3 years	4 years	5 years	6 years
15.4%	50.5%	26.8%	6.2%	0.8%	0.2%

Table 1 contains an overview over the distribution of the duration of the subsidized projects. More than half the projects in the analysis are of 2-years' duration. About 15% start and end in the same year. Only about 7.2% of the projects are longer than 3 years.

4.2 Variables for evaluation

Though being aware of the various shortcomings of patent counts as R&D output indicators (Freeman & Soete, 1997), we used patent applications to evaluate the impact of the subsidies, testing Hypothesis 1. This output indicator was selected due to its availability, which allowed us to carry out the evaluation on the basis of a rather large sample of participating companies. Furthermore, Hagedoorn and Cloudt, in a comparison of potential innovation output indicators, show that patents "could be a more than acceptable indicator of innovative output"(Hagedoorn & Cloudt, 2003). For each firm we used its number of patent applications at the National Board of Patents and Registration of Finland (NPR); data for the years 1985 to 1999 was available. We retrieved the employment of each of the companies from 1994 to 2000 from Statistics Finland's business register to be able to test Hypothesis 3.

³As the data only indicated the starting year and the termination year of the project, we counted both years as full years.

4.3 Firm characteristics for matching

The characteristics to achieve the similarity of the matched companies capture various dimensions of the firm.

4.3.1 Characteristics of the companies

The characteristics of the companies both the subsidized companies and the not subsidized ones are drawn from Statistics Finland's business register. To characterize the firms we extracted the turnover and the employment from the business register for each year from 1994 to 2000. Both turnover and employment are used as size indicators. However, matching on both variables also makes sure that the matched companies exhibit a comparable performance in terms of labor productivity.

To ensure that companies are comparable we only match companies with a comparable set of activities. This information is contained in the sectoral classification of the companies, which is also retrieved from Statistics Finland's business register.

4.3.2 Patenting history

In the matching process we have to make sure that companies are matched, which show a comparable past technological performance. This is necessary as to exclude the effect that a clever program administrator might have on the outcome of the impact evaluation.

To clarify this point, imagine that an internal assessment of the program within the granting organization focuses on the technological performance of the program participants. A rational and opportunistic program administrator would then choose program participants that have exhibited a superior technological performance in the past, as they are more likely to exhibit a better technological performance in the future.

We have to exclude this effect by including a measure of past technological performance of the firms in the matching process. To approximate the level of accumulated technological knowledge and experience we computed the patent stock for each company using a yearly depreciation rate of 10% p.a. The stock of patents bases on the patent counts for the years starting from 1985.

4.3.3 Knowledge-intensity

To characterize the knowledge intensity of the firms we use data from the Finnish employment register which enables us to assess the number of employees in the companies with a high level of education. We regard employees with a degree from a polytechnic high school and above as having a high level of education.

4.3.4 Time

Concerning the time variable we have to make sure that the subsidized company and the not subsidized company are observed at the same point of time. Additionally, the matching also has to refer to the companies' characteristics before the subsidized projects started. Hence we match companies on their characteristics in the year preceding the start of the project.

4.4 Constructing the data sets

Basically, we generate two different data sets containing the observations of the subsidized companies and the observation of the not subsidized companies using the data introduced above.

The matching procedure demands that the group of not subsidized companies is comparable to the subsidized companies. Comparability in our particular case also relates to the strategic orientation of the companies. We require of both groups of companies to have a comparable strategic orientation towards innovative activities, since the subsidies only appeal to those companies. As a proxy for the strategic orientation we use the information about R&D activity contained in the R&D survey (from 1985 to 2000), the three waves of the Community Innovation Survey in Finland (1991, 1996 and 2000) and the database of Finnish innovations (Sfinno). The R&D survey as well as the Community Innovation Survey is conducted by Statistics Finland. The database of Finnish innovations is built and maintained by VTT Technology Studies (Palmberg, Leppälähti, Lemola, & Toivonen, 1999, Palmberg, Niininen, Toivanen, & Wahlberg, 2000)

Only companies that have reported R&D efforts at least once are included in the sample of the non subsidized companies. The data set of the not subsidized companies contains 83,168 observations for 11,797 companies whereas the data set of subsidized companies contains 1,894 companies.

5. Empirical Analysis

In this section we present the results of the matching allowing us to carry out the assessment of the impact of the subsidies on the innovation output and the labor demand of the subsidized firms.

5.1 Matching

Before matching, the sample of subsidized companies differs significantly from the sample of the not subsidized companies. On the average the former are larger than the latter. They have a higher turnover, a larger employment with high education and a higher technological experience measured by the patent stock. Table 2 contains the population averages of the characteristics and tests for equality of means, which is rejected for any single characteristic.

Table 2: Sample of subsidized and not subsidized firms before matching

Variable	Not subsidized	Subsidized	Sig.
Employment ⁺	2.55	2.74	***
Turnover ⁺	6.57	6.77	***
High ed. empl. ⁺	2.45	2.70	***
Patent stock	0.11	0.21	***

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1; ⁺ indicates variables in logs.

The target of the matching procedure is to remove the differences and construct two comparable samples that differ only in the fact that one sample contains the subsidized firms and the other one contains not subsidized firms. Then, the differences in the observed patenting and employment are only caused by the subsidy rather than by the different composition of the sets of companies.

We conduct the kernel based matching discussed in section 3.2 using the firms' characteristics such as employment, turnover, highly educated employment and patent stock. Additionally we control for the time variable and the sector of firms' activity. The matching is performed on the characteristics of the companies in the year before the project starts.

Table 3 summarizes the sample of subsidized and the sample of non subsidized companies after the matching. Now we cannot reject the equality of means.

Table 3: Sample of subsidized and not subsidized firms after matching

Variable	Not subsidized	Subsidized	Sig.
Employment ⁺	2.71	2.74	
Turnover ⁺	6.74	6.77	
High ed. empl. ⁺	2.68	2.70	
Patent stock	0.21	0.21	

Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1; ⁺ indicates variables in logs.

5.2 Impact analysis of the program

In the following sections we will discuss the impact of the public subsidies on the innovative output in terms of patenting. Eventually we discuss the impact of public subsidies on the development of the companies' labor demand.

The fact that the subsidy program is directed to R&D projects means there is no single point in time that can be referred to as a reference. Rather do we have to observe the development of the innovation output and the labor demand over time. We analyze the patenting behavior during the project, the results referring to this time interval are labeled *during project*. Some of the patents being research results of the project are filed after the project ends. In the following evaluation the patents being filed in the year after the project ends are accounted for and labeled *after project*. The results labeled *total* combine both the patents during the project as well as those after the project.

The potential employment impact of the project sets in with a time lag that cannot be specified *a priori*. Therefore, we observe the employment record of the companies over a time period of 4 years after the firm started to receive funding.

5.2.1 Effect on patenting

We evaluate the effect of the public subsidy in terms of the average patenting behavior of the group of subsidized and the group of not subsidized firms. To eliminate both time-invariant individual effects and common time effects that affect both the subsidized and the not subsidized firms, we focus on the difference-in-difference,- i.e. the difference of annual patent output after or during the project compared with the patenting output before the project (Blundell & Costa Dias, 2000, Jaffe, 2002). Hence, in combination with the matching approach, we estimate the effect by means of a conditional difference-in-difference approach.

Table 4 reports the average change in patenting for both groups and a significance indicator of the t-test testing for the equality of the means. The availability of the patenting data requires that we restrict the sample to projects that terminated in 1999 or earlier for the measurement of the effect during the project. For the estimation of the total and the after project impact we have to restrict the sample to projects that ended in 1998 or earlier. The sample size is also reported.

Table 4: Overall impact of the program

	Patenting	N	Not subsidized (I)	Subsidized (II)	Sig
(i)	Total	483	-0.0198	0.0154	.
(ii)	During project	858	-0.0153	0.0410	**
(iii)	After project	483	-0.0345	0.0248	.

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1. Column (I) and column (II) contain the average change in patenting per year, where the patenting in the year before the project is the reference.

We observe that had the companies not been subsidized companies, they would have reduced their average annual patenting over time. At the same time, however, the subsidized companies experience an increase in average annual patenting activity. The average level of patenting for a subsidized firm during the project is 0.04 patents per project per year higher than the level of patenting in the year preceding the funding. Had the company not been funded, the level during the same period of time would have been 0.015 patents per project per year lower than in the reference year. Table 4 shows a significant positive effect as the average patenting per year per project is higher with subsidies than it would have been had the subsidized companies not been subsidized. Hence Hypothesis 1 is supported by our findings.

As illustrated in Table 1, the subsidized projects are of different durations. A detailed analysis of the effect accounting for the differing durations seems mandated. Table 5 shows the total impact of the project broken down into project durations of one year to four years. The impact of projects, which have not terminated by 1998 cannot be assessed fully as the latest available patent information dates from 1999. We give the latest possible start year of the projects in the column labeled *Start* for each project duration.

We observe a positive impact of the subsidy for any project length. The impact for the two-year projects is significant; the impact of the one and three-year projects is only mildly so. Also, the four-year projects turn out not to be of significant impact, although the absolute value of the average change in patenting per year would suggest otherwise. The significance level could be caused by the small number of observations that are included in the analysis.

Table 5: Project duration and impacts

Duration	N	Start	Not subsidized(I)	Subsidized (II)	Sig.
1 year	193	...1998	-0.0420	0.0103	.
2 years	472	...1997	-0.0290	0.0240	*
3 years	158	...1996	-0.0127	0.0870	.
4 years	35	...1995	-0.0063	0.3142	.

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1. Column (I) and column (II) contain the average change in patenting per year, where the patenting in the year before the project is the reference.

Summarizing the analysis up to this point, we observe support for the hypothesis that public R&D subsidies have a positive impact on the generation of innovation output.

5.2.2 Effect on labor demand

To investigate the impact of the public subsidies on the firms' labor demand of firms we have to be guided by two considerations. First, previous studies have established a considerable time lag between the introduction of an innovation and its subsequent impact on the labor demand. As patenting is associated with the invention stage rather than with the innovation stage we can expect an even longer time lag. Second, as we established the most significant positive effect only for two year projects, we should base our further investigation only on those projects.

Additionally, we restrict the sample to the projects starting in the year 1996. The two years projects end in 1997. The availability of the employment data up to the year 2000 allows for investigating the impact up to three years after the project ends. Before turning to the analysis of the employment effect we have to investigate two prerequisites:

First, the matching procedure above produces a sample of subsidized firms and a sample of not subsidized firms that are corrected for selection bias. This feature does not necessarily translate into the smaller subsample being investigated now. The upper part in Table 6 reveals, that even for the subsample of two years projects started in the year 1996 the matching generated comparable samples of subsidized and not subsidized companies. Testing for the equality of the averages of the characteristics used for matching does not reject.

Table 6: Employment effect

Variable	Year	Non subsidized	Subsidized	Sig.
Employment ⁺	1995	2.64	2.68	
Turnover ⁺	1995	6.87	6.84	
High ed. empl. ⁺	1995	2.36	2.39	
Patent stock	1995	0.15	0.16	
Patenting change	1995-1998	-0.0197	0.0347	
Empl. Growth	1994 - 1995	-0.0874	-0.1160	
Empl. Growth	1996 - 1997	0.1072	0.1343	
Empl. Growth	1996 - 1998	0.0492	0.1090	
Empl. Growth	1996 - 1999	-0.0036	0.0759	.
Empl. Growth	1996 - 2000	-0.0890	0.0366	**

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 The effects given here only refer to the two-year projects starting in 1996.

Although the matching characteristics are comparable in the samples, subsidized companies show a higher patenting activity compared with the non-subsidized companies. The subsidies for the two-year projects starting in 1996 have a positive impact on the generation of innovative output as the change in patenting is higher for the subsidized group than for the control group. This impact is not significant at the 10% level, though.

Fundamentally, the analysis here looks at differences in the mean of some characteristics of the sample of subsidized and the sample of non-subsidized firms. We deduce an impact if there is no difference in the mean of some characteristic before the public funding but there is a significant difference in the characteristics after or during the public funding. This brings us to the second prerequisite. We can only deduce an employment effect if, and only if, the employment variable before the publicly subsidized projects does not differ. Table 6 reveals that on average the companies in both samples experience a reducing employment in the years 1994 to 1995, which does not differ significantly between the group of subsidized companies and the group of not subsidized companies. Even though the employment growth is not a characteristic used in the matching process, the matching still manages to create samples that do not differ in terms of employment growth before the R&D subsidy.

In assessing the labor demand effect of public R&D subsidies we have to investigate the development of the employment during the project and after the project. During the project the employment growth rates do not differ significantly between the samples of subsidized and the sample of not subsidized companies. After the project, however, we experience a positive, but declining, average employment growth rate in the sample of subsidized companies. In the sample of not subsidized companies we see a negative and declining

average growth rate of employment. The differences are significant for the average annual employment growth rates for the time from 1996 to 1999 and to 2000.

As the sample of subsidized companies and the sample of not subsidized companies are comparable according to the chosen characteristics, and, furthermore, do not exhibit differential employment growth prior to being subsidized, we can attribute the observed differential growth in employment to the public funding. This finding supports Hypothesis 3 and establishes a positive impact of the R&D subsidies on the labor demand of the subsidized companies.

6. Conclusion

In this analysis we investigate the employment effect of public subsidies for innovation. We use a sample of Finnish companies that have received subsidies for their innovative efforts. We match those companies with companies that have never received any subsidy for R&D. The results of our study support the hypothesis that public subsidies have a positive impact on the innovative output of companies. We also establish an empirical link between the funding and the companies' subsequent labor demand. Public subsidies for innovation are found to have a positive influence on the companies' employment growth.

In the Finnish case investigated here the positive impact of the policy of direct involvement through R&D funding can be attributed to three facts. First, there is an incentive for firms to collaborate built into the funding criteria of the National Technology Agency (Schienstock & Hämäläinen, 2001) Empirical evidence suggests that this incentive does indeed increase the companies' propensity to collaborate for innovation. Second, although there are generally some conflicting results concerning the complementarity of public and private R&D spending (David, Hall, & Toole, 2000) studies in Finland suggest there is complementarity between public R&D subsidies and private investment in R&D (Ali-Yrkkö & Pajarinen, 2003, Lehto, 2000). Therefore, public R&D subsidies lead to an increase in nominal R&D inputs. Finally, the increased resources for R&D do not face an inelastic labor supply for engineers and scientists in Finland as the Finnish innovation system has been able to constantly increase the supply of science and technology graduates (Georghiou, Smith, Toivanen, & Ylä-Anttila, 2003). The increased resources for R&D do not translate into rising wages for engineers and scientists rather do they increase the real input in R&D.

As the subsidy program directly targets the R&D activities of the subsidized firms, we can evaluate the impact of the program in terms of R&D output and labor demand. The focus on the effects of the program and the neglect of the magnitude of the resources spent on the program puts the effectiveness rather than the efficiency of the program at the center of our study.

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