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PUBLIC R&D FUNDING AND ENTREPRENEURIAL INNOVATION

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ABSTRACT: This study does not find any significant direct relationship between the public R&D funding and the firms' innovation output. The firms obtaining the public R&D support were not performing significantly better, on average, than others. However, we find evidence that the public R&D finance has substantially influenced the innovation output of the firms that have undertaken certain types of innovations activities. Particularly, public funding targeted to the firms focusing on new business areas in their R&D projects seems successful. Certain types of collaboration seem to also generate better entrepreneurial performance in terms of innovation. Those large firms that have more intensively collaborated with the SMS firm partners in their publicly funded R&D projects have filed more patent applications than other companies.

JEL Classification: L10, O33, O38

Key words: innovation, public R&D subsidies, technology policy

1. Introduction

The literature provides substantial evidence of the positive effects of public R&D subsidies on the firms' innovation performance but, overall, the reported research findings are conflicting (see, e.g., Czarnitzki et al, 2004; David et al, 2000; Lach, 2000; Mohnen and Garcia, 2004). The question of the economic impacts of public R&D support is particularly relevant for such countries in which the private sector's R&D investments are already relatively large and the further need for public R&D subsidies may be questioned (such as in Finland that ranks among the highest in terms of R&D/GDP ratio). Our empirical analysis aims at detecting the impact of the public R&D funding on the Finnish firms' innovation performance. We take into account the issue that is often emphasized, the fact that the selection process of the projects that receive public funding is not random[1], and use estimation techniques that control for the non-random sample selection mechanism.

There are relatively few econometric studies investigating the relationship between public R&D finance and entrepreneurial innovation among the Finnish companies. Ebersberger's (2004) empirical examination suggests that the Finnish firms that received public R&D funding for their projects terminating during the second half of the 1990s patented, on average, more innovations than non-subsidized companies. Also, several empirical studies find that public R&D funding has not crowded out but increased the Finnish firms' private R&D investments (see Lehto, 2000; Niininen ja Toivanen, 2000; Ali-Yrkkö, 2004).

The question that is less often addressed in empirical studies is how the public R&D funding affects to the firms' innovation process via the selection of the subsidized projects and further whether and how this selection influences the firms' innovation performance. In Finland,

[1] Particularly, it seems possible that the firms that have greater innovative capabilities present more viable or potentially successful R&D project plans, and are more likely to be selected to obtain public R&D finance. Then, the estimated coefficient of the public R&D finance variable explaining variation in the firm's innovation performance may be significantly upward biased unless the effect of the non-random selection of the firms to obtain public R&D funding is taken into account.

Tekes (the Finnish Funding Agency for Technology and Innovation) – that is the principal government organization providing public R&D funding for the firms[2] – has publicly announced the selection criteria it uses when it decides whether to provide funding for the proposed projects. We empirically examine whether the project selection criteria (i.e. project and firm characteristics) emphasized by Tekes are positively related to the firms' innovation performance. We use data from the Finnish firms which received public R&D support during the years 1999-2003 and, in comparison, data from the companies that applied for public R&D support but had their funding application rejected and thus received no public financial support for their R&D activities.

The paper is organized as follows. Section 2 introduces our data and sheds light on some key firm and project characteristics. Section 3 investigates the relationship between Tekes funding and firm's innovation performance. Section 4 concludes.

2. Innovation performance: descriptive analysis

2.1 Some key firm and project characteristics

Our data comprise information from the follow-up reports[3] of 976 Finnish companies that received funding from Tekes for, in total, 1618 projects ending during the years 1999-2003. The firms of which about one third are small and medium sized companies (i.e. firms employing maximum 250 people and having maximum annual turnover of 50 million euros) and two thirds large companies (i.e. firms employing more than 250 people and having annual

[2] In 2007, Tekes provided in total 269 million euros for 2120 entrepreneurial R&D projects. During the second half of the 1990s Tekes finance covered over 15% of the Finnish firms' total R&D expenditures, whereas since 2000 the corresponding share has been around 11%.

[3] The follow-up reports designed by Tekes to evaluate the effectiveness of their funding are filled by each project leader after the completion of the subsidized project.

turnover greater than 50 million euros) were selected from the list all Tekes funded firms by random sampling. The total number of firms receiving funding from Tekes during the sampled time period was 1700, i.e. our sample covers almost 60% of all Tekes funded firms. We also have data from 259 firms that applied for Tekes funding but their application was rejected and no public financial support granted. Moreover, we have information on the key characteristics of the planned projects, both accepted and rejected, that the Tekes officers have used while making a decision whether or not to grant financial support for the project. This pre- and post-project information extracted from the database of Tekes is combined with the Asiakastieto[4] financial data concerning the sampled firms during the years 1999-2004 and with the data on the firms' patents that is obtained from the database of National Board of Patents and Registration of Finland. The compiled database provides a rich set of information based on both the firms' subjective reporting and the official statistics concerning their functioning.

The majority of the Tekes funded projects obtained subsidies, whereas about one quarter were funded by the loans and 13% by the capital loans. Quite commonly, for almost 28% of the projects, the firm received both the subsidy and the loan/capital loan. About one third of the projects that were granted Tekes financial support were R&D projects, while the rest focused merely on the development activities. Almost all (i.e. 95%) of the R&D projects received subsidies, while 14% of them had a loan from Tekes. One third of the development projects were funded by the loan and 20% of them by the capital loan offered by Tekes.

The average subsidy per project exceeded 140 000 euros, while the average loans and capital loans were somewhat higher, about 180 000 and 160 000 euros, respectively. The average total funding per project, including often both subsidy and loan, was almost 180 000 euros. The data show a very large variation in the size of the funded projects: the smallest project

[4] Asiakastieto is a Finnish company that collects, maintains and sells firm-specific financial and credit information.

received less than 10 000 euros from Tekes, while the public finance of the largest one exceeded 3.5 million euros.

Table 1 illustrates the characteristics of the data concerning the distribution of Tekes funded projects over the sampled firms and years. More than two thirds of the firms were undertaking one or more Tekes funded projects during the years 1999-2001, and about half of the companies had no Tekes projects after 2001. There were also a substantial number of firms – almost 30% of companies (i.e. 278 firms) - that had not begun their first Tekes financed project before the year 2001.

Table 1. Sampled firms with Tekes financed projects ending 1999-2003

Year	Number of firms undertaking Tekes project	Share of firms undertaking Tekes project	Share of firms that had not yet began any Tekes project (%)	Average number of projects	Max number of projects
1999	666	68.66	30.31	1.52	41
2000	694	71.40	28.60	1.47	38
2001	646	66.53	3.91	1.42	30
2002	475	48.92	0.31	1.31	15
2003	243	25.00	0.00	1.20	5
2004	0	0.00	0.00	0.00	0

As our database comprise information on the financial and patenting activities of the sampled firms for the years 1999-2004, it enables us to study the performance of companies before and after they received public R&D support. Annex 1 takes a more detailed look on how the data is distributed by the beginning and ending years of the projects among the sampled firms. Moreover, as our data further comprise 259 companies which had filed a funding application to Tekes but had it rejected, we can also compare the subsidized companies' innovation behavior to those that didn't receive any financial support from Tekes.

2.2 Government R&D support and innovation performance

We first explore the subjective responses of the firms concerning the impacts of Tekes R&D support on their innovation performance, and then use official patent statistics to shed light on the same question. About 65% of the firms that received funding from Tekes reported that they had not undertaken the project without the financial help of Tekes, and 90% of the respondents told that Tekes finance affected the implementation of their research and/or development project.

Figure 1. Firms' subjective reports on the project-level impacts of Tekes finance

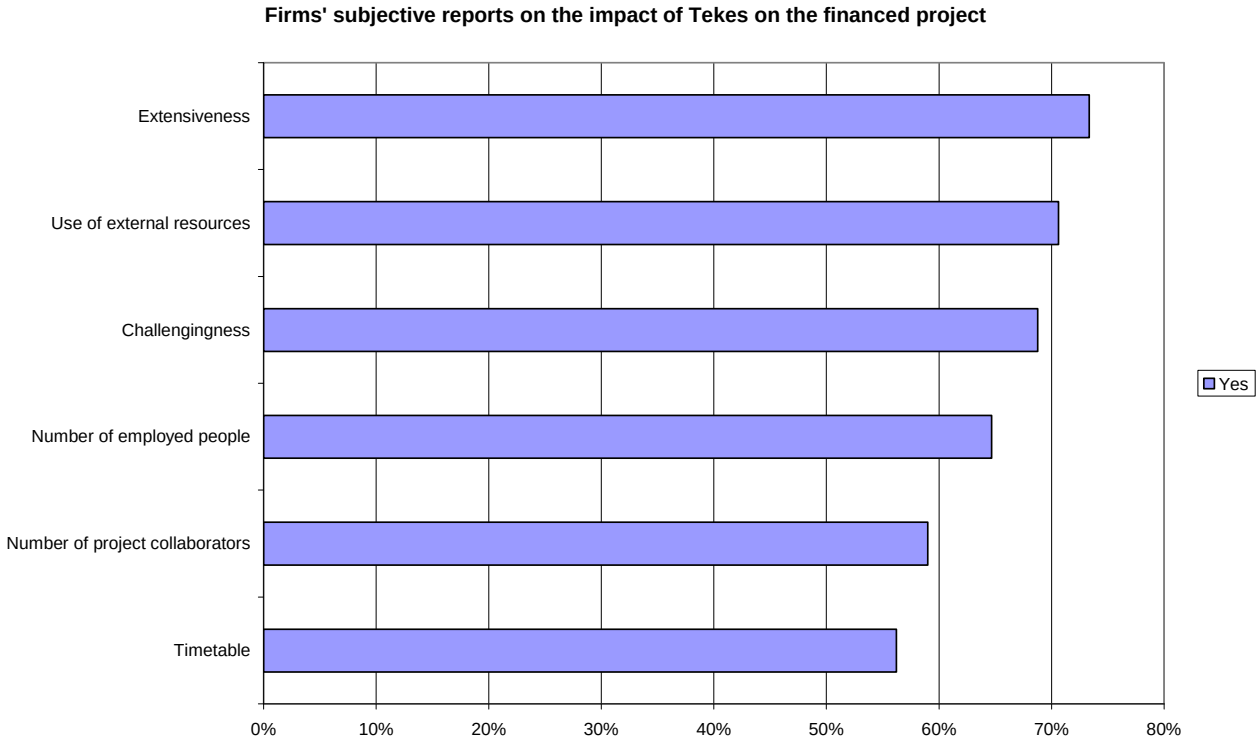


Figure 1 summarizes the assessment of the project leaders of the influence of Tekes finance on the financed project. About 70% of the respondents told that, due to Tekes finance, they undertook a more extensive and challenging project and were utilizing more external resources that they had otherwise done. Also, close to 60% of the respondents told that, with

Tekes finance, they employed more people and collaborated with the greater number of partners.

Figure 2. Firms' subjective reports on the firm-level impacts of Tekes finance

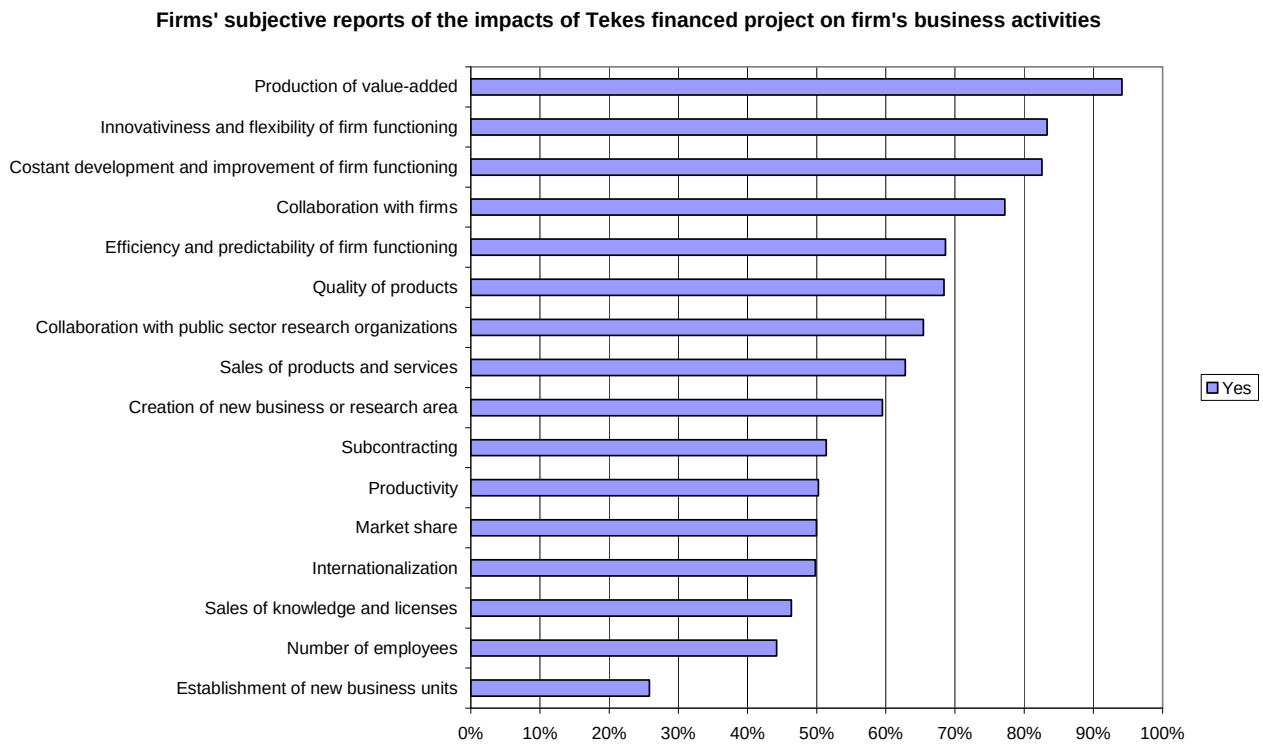
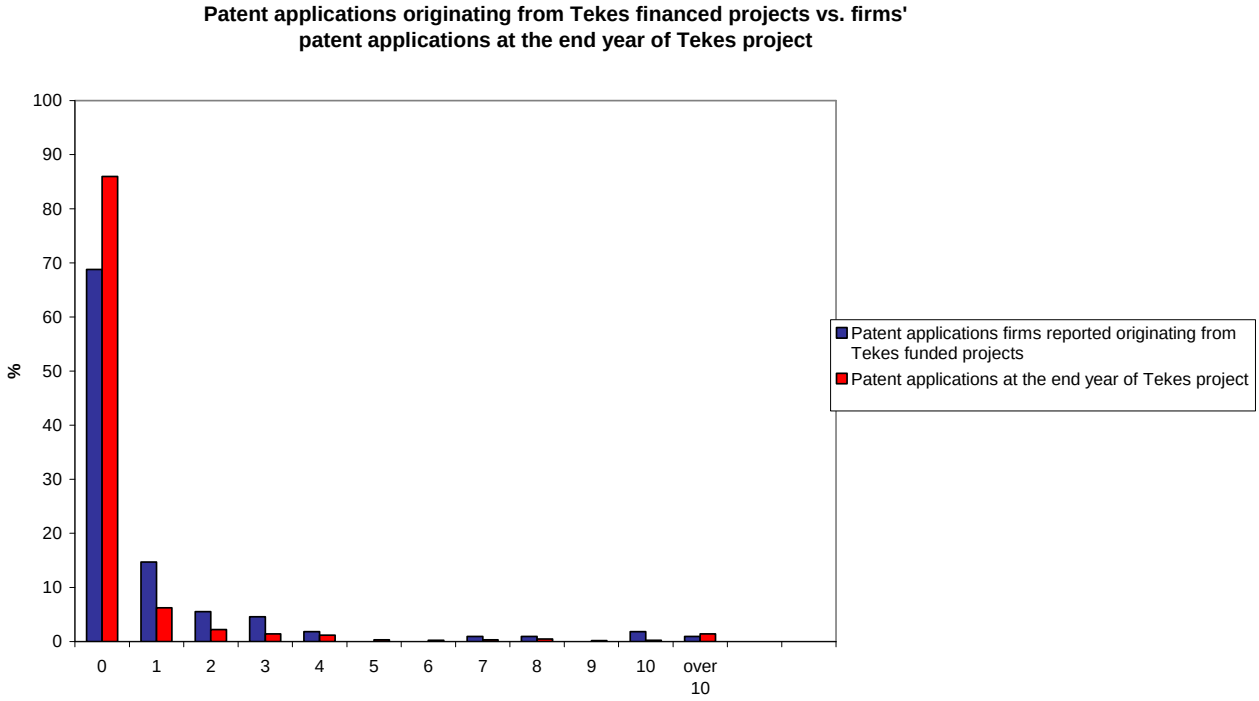


Figure 2 shows how the project leaders evaluated whether or not their Tekes financed project influenced 16 business activities. Over 90% of the respondents assessed that the project contributed positively to the creation of value-added in their company, and over 80% believed that the project increased the firm's innovativeness and improved its functioning. In the light of these subjective survey responses the firm-level impacts of Tekes financed projects on the firm's innovation process seem highly positive.

We measure a firm's actual innovation performance by the total annual number of filed patent applications extracted from the official patent statistics[5]. This measure can be justified as the

[5] We unfortunately have the firms' subjective reports on the number of patent applications originating from their Tekes financed projects concerning only 109 projects.

Figure 3. Firms' patent applications: reported Tekes financed project output vs. official patent statistics at the end year of the project



public R&D support may not only increase a firm's innovation directly via the funded projects but it may also promote the firm's R&D activities that further materialize as the patentable innovations (see, e.g., David et al, 2000). Figure 3 shows that the distribution of the number of patent applications that the firms reported originating from the Tekes funded projects and that of the number of the firm's patent applications as they appear in the official patent statistics at the end year of the firms' Tekes financed projects are not very different though.[6]

We first visually examine our dataset concerning the innovation performance of the firms that received Tekes project funding decisions during the years 1999 and 2000. These years were selected as we have sufficient overlapping data from patents and the project funding decisions

[6] We also used the Wilcoxon Matched-Pairs Signed-Rank test to evaluate whether the firm's reports on the number of patented applications originating from the Tekes funded projects differ substantially in size from the total number of patents the firm filed at the end year of the project. The H_0 hypothesis is that the difference between the firms' subjectively reported number of patent applications and the actual number of filed patent applications has median value zero. The 14 small and medium size companies reported all zero patent applications resulting from their Tekes projects – this information is consistent with the official patent statistics. The Wilcoxon Matched-Pairs Signed-Rank test further suggests that there are no statistically significant difference (at p=0.01) between the number of patents the firms have reported arising from their Tekes funded projects and their annual filed patent applications when we include all 109 companies to the analyzed sample.

for the analysis only from these two years. Figure 4 and 5 show, respectively, the valid number of patents and the number of patents firms have applied for in Finland at the sample years.

Figure 4. Firms' valid patents in Finland at the end year of Tekes project funding decision

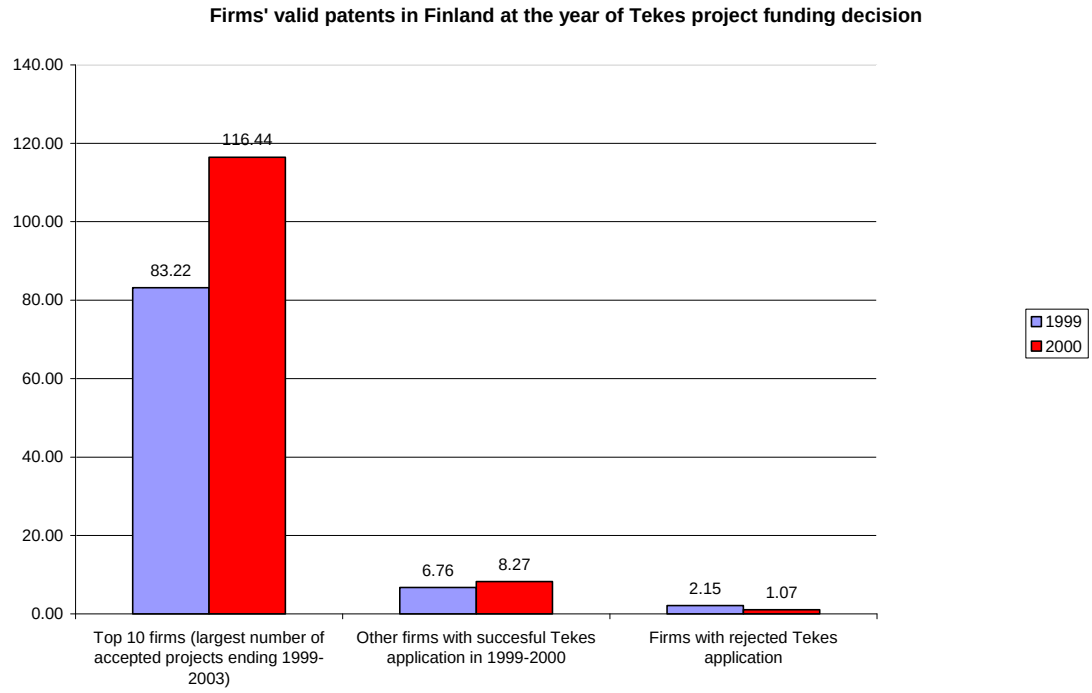
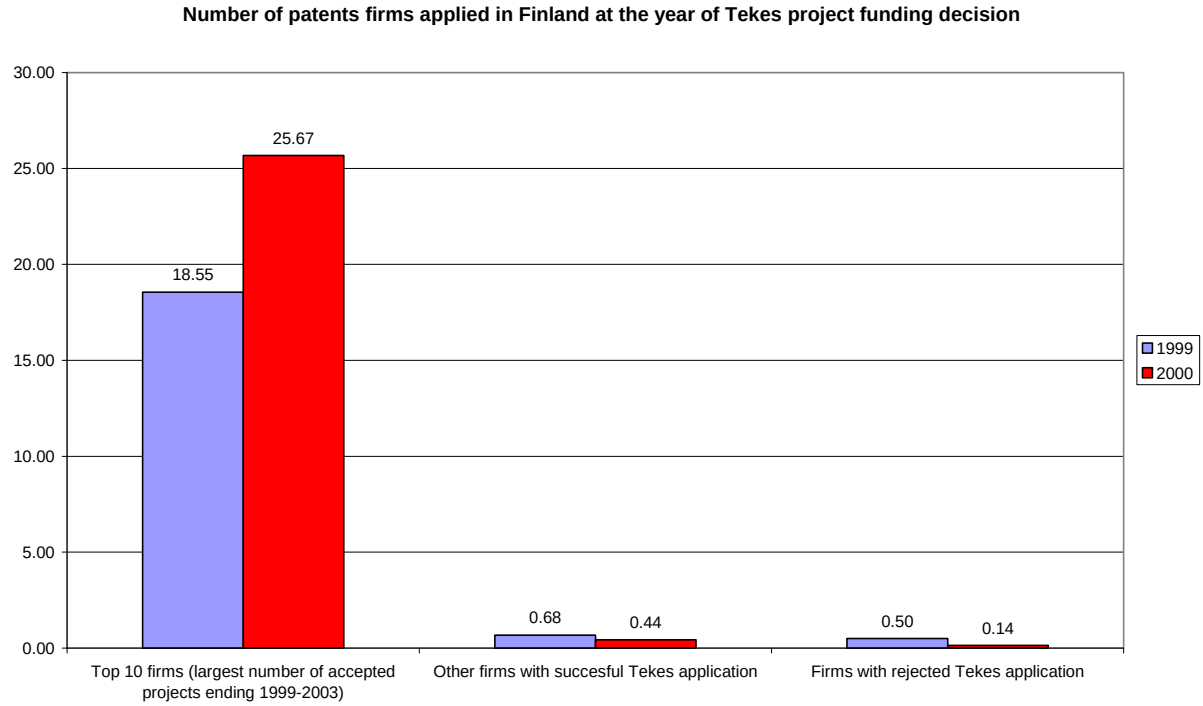


Figure 5. Number of patents firms applied in Finland at the year of Tekes project funding decision

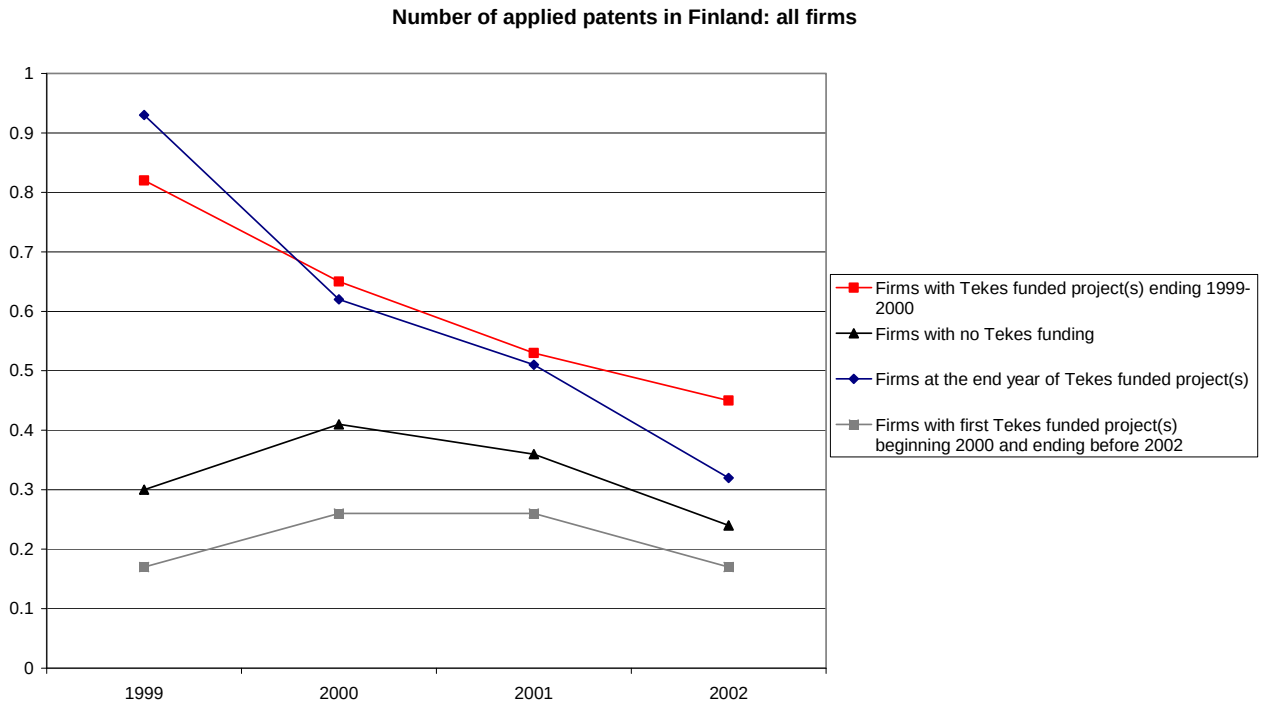


Figures 4 and 5 illustrate that the firms that obtained a positive funding decision from Tekes were holding, on average, a larger stock of patents and also filed slightly more patent applications than the firms of which project application Tekes rejected. The top 10 firms in regard to the number of accepted Tekes funded projects, instead, differ substantially from the rest of the sample. These are large firms of which average number of patent applications varies, approximately, between 18 and 25, while all firms with successful Tekes applications and rejected firms have applied, on average, less than one patent. The difference becomes even more dramatic when we look at the patent stocks of companies. While the average number of valid patents held by the top 10 firms is about 117 in 2000, the correspondent number is about 8 among the rest of the sampled firms receiving a positive finance decision from Tekes, and about 1 among the firms that had their application for Tekes finance rejected. The top ten firms that have obtained R&D funding from Tekes clearly form a group of outliers in the sample – it is important to take this into account in the empirical analysis exploring the impact of Tekes funding on the firm's innovation behavior.

Figure 6 and 7 compare the numbers of filed patent applications during the years 1999-2002 between certain subgroups of the sampled firms. Our aim is to shed preliminary light on the question how firms that didn't receive Tekes funding differ, on average, from those of which Tekes funded projects ended during the sampled years, and those of which Tekes funded project began during the sampled years. We chose a group of firms of which first project began in the year 2000 and ended by the end of 2001 so that we can observe how the firms' patenting activities have changed between the three stages: before Tekes funded project, during the project, and after the project. The top ten firms of which patenting behavior dramatically differs from the rest of the sample are removed from the data for the calculations of the averages of figure 7.

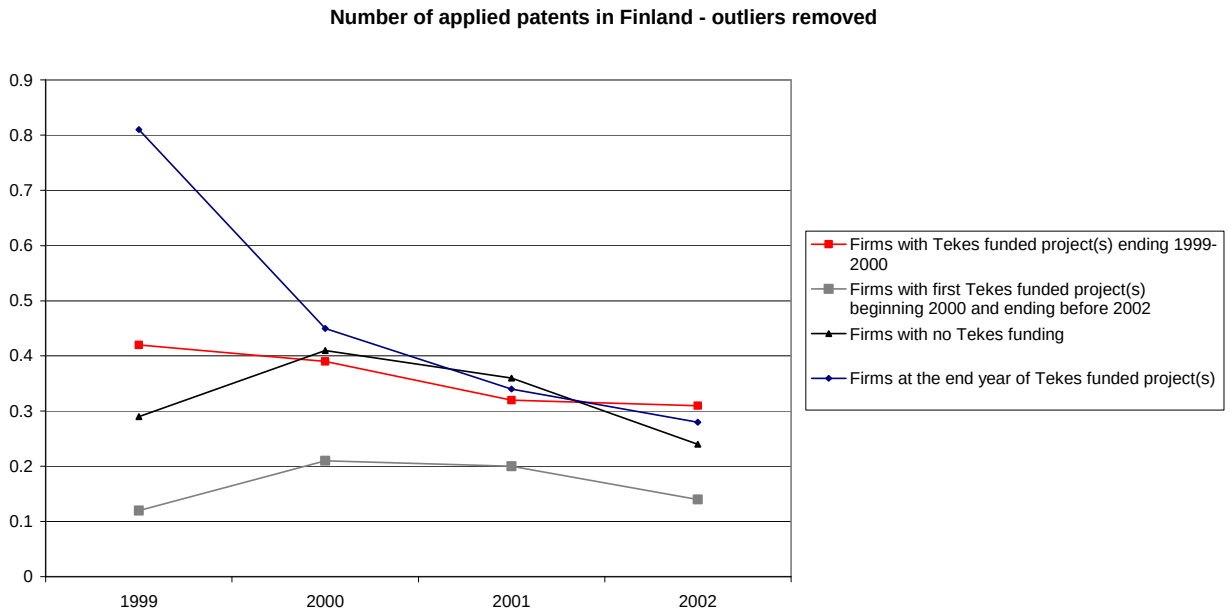
The firms that had Tekes funded research and/or development projects ending during the time period 1999-2000 and those at the end year of their Tekes project seem to have more filed patent applications, on average, than other companies. However, if we look at the average annual number of filed patents among those firms which had their first Tekes funded project(s) during the years 2000 and 2001, we find that these companies perform worse during all stages (i.e. before, during, and after the project) than the firms that didn't have any Tekes funded projects. There is a slight increase in the number of patent applications filed during the years 2000 and 2001, but we observe a similar increasing pattern in patenting activities among those firms that didn't receive Tekes finance. Figure 7 shows that when the ten outliers are removed from the sample, the differences between the companies that received Tekes funding and those that didn't almost vanish after the year 1999.

Figure 6. Number of applied patents in Finland 1999-2002 among the sampled firms: all firms



There is no straightforward explanation for the relatively low performance of the firms that undertook Tekes funded projects during the years 2000 and 2001. A possible underlying reason is that Tekes do not select firms randomly from different industries but it emphasizes certain technology areas, and this emphasis further changes over the years. The establishment of the technology programs for certain sectors means that the funding is biased towards firms in these fields, and as the underlying differences in the firms' propensity to patent vary between the sectors (e.g. the Finnish software firms are not very active in patenting as the IPR law strongly restricts the patentability of software related innovations in Finland, whereas in the electronics industry patenting is relatively often used as a means of the IPR protection), this may result differences in the average patenting behavior over the years among the firms funded by Tekes. The industrial dummy variables are created and used in the econometric analysis to control for the differences in the firm's propensity to patent across industries.

Figure 7. Number of applied patents in Finland 1999-2002 among the sampled firms: outliers removed



Clearly, more sophisticated analytical methods (i.e. econometric modeling and analysis) that simultaneously control for the industry and firm specific differences in the firm's propensity to patent are needed to make any conclusions about the impacts of government R&D funding on the innovation performance of the sampled companies.

Table 2. Filed patent applications before and during Tekes financed project

Change in the number of firm's patent applications: before Tekes project vs.during Tekes project		
	Number of observations	Percent
Decrease	46	10.43
No change	343	77.78
Increase	52	11.79
Total	441	100
Mean (median) change	441	-0.02 (0.00)

We further take a look at the sample of the firms that received Tekes funding to see whether the number of patent applications the firms filed before receiving any Tekes funding differs from the number of patents filed during the years of Tekes financed project.[7] We use the annual averages of the patents filed before/during the Tekes project during the sampled years 1999-2003.[8] Table 2 shows that the majority of Tekes funded firms (i.e. about 78%) didn't

[7] As our patent data begins from the year 1999, we don't have "before Tekes project" patenting information from the firms of which first Tekes project began on or before 1999 and these firms are thus dropped from the sample.

[8] In other words, if the firm had a Tekes project during the years 2001-2002, we calculate the patents filed before the project as the average number of patent applications filed during the years 1999-2000, and during the project patent applications as the average number of patent applications the firm filed in 2001-2002.

apply more (or less) patents after receiving Tekes funding. About 12% of the firms filed more patent applications during their Tekes project than before it, while 10% filed less. The mean and median differences between the number of patents the firm filed during and before Tekes project are, respectively, -0.02 and 0.[9] In other words, the descriptive analysis of the data shows not much difference in the innovation performance of the firms before and during the Tekes project. We next develop a more sophisticated econometric model that takes into account the potential sample selection bias to investigate the impacts of public R&D funding on firms' innovative behavior.

3. Empirical findings

3.1. Empirical model: patent production function with sample selection

Our econometric model is divided into two parts: the selection equation and the performance equation. First, the selection equation investigates whether the differences in the firms' innovative output affect to the funding decisions of Tekes. We use the dependent variable measuring whether the firm's funding application to Tekes was successful: the variable TEKES_FUND takes value 1 if the firm received funding for its project ending during the years 1999-2003, and 0 if Tekes rejected the firm's project application. Our key explanatory variable here is the firm's innovative output, the number of valid patents the firm held in Finland when it applied finance from Tekes (the variable PATENT_VALID). A positive (negative) statistically significant estimated coefficient of this variable means that the project

[9] We further checked the possibility that only the number of patents the firm filed at the end year of Tekes funded project differs from its patenting prior to the Tekes funded project. About 83% of firms had no change in their patenting behaviour, while 11% (6%) filed less (more) patent applications at the end year of Tekes project than before the project.

proposals of more (less) innovative firms (prior to the Tekes funding decision) are accepted and funded more often than others.

The government officers deciding whether they grant financial support for the firm's R&D project use certain firm and project characteristics as the selection criteria. It is also interesting whether the publicly announced funding principles of Tekes explain statistically significantly differences in the actual project finance decisions. Tekes emphasizes that "high-quality, advanced technology and effective networking" are essential criteria in its R&D funding decisions. Additionally, the project's long-term effects, such as how the project is estimated to contribute to employment and exports are considered in the evaluation process."[10] Tekes further defines that the funded enterprise projects are selected by evaluating:

- the business to be generated
- the technology, innovation and competence to be developed
- the resources available
- the cooperation to be developed and used
- the social and environmental well-being factors to be promoted
- the impact of Tekes funding and expert services

To investigate the impact of these selection criteria on the actual project funding decisions, we add all available information we have on the above factors to the set of explanatory variables of the Tekes funding selection equation (see Table 3 for a detailed description of the variables used in the analysis).

The *networking and collaboration* criteria are strongly stressed in Tekes' funding decisions as the collaborative projects are expected to result in more wide-spread knowledge spillovers and thus greater benefits to a society. We measure the networking dimension of the suggested

[10] Source: http://www.Tekes.fi/eng/Tekes/rd/evaluation_criteria.htm

Table 3. Description of the variables

Description of variable	Variable name	Mean	Standard deviation
Dependent variables:			
Dummy variable that gets value 1 if firm has received finance for the project ending between 1999-2003, 0 otherwise.	TEKES_FUND	0.87	0.34
Dummy variable that gets value 1 if firm has applied one or more patents in Finland at year t, 0 otherwise.	PATENT_DMY	0.33	0.47
Number of patent applications firm has filed in Finland at year t.	PATENT_COUNT	0.47	4.88
Explanatory variables:			
Log firm's annual R&D expenditures.	RD	-1.09	2.05
Log firm's annual total finance obtained from Tekes.	TEKES_RD	-6.01	3.17
Dummy variable that gets value 1 if firm is under-taking Tekes financed project at year t, 0 otherwise.	TEKES_PROJ	0.44	0.50
Dummy variable that gets value 1 in case of the R&D projects, and 0 in case of development projects.	RD_PROJECT	0.33	0.47
Number of valid patents firm has in Finland at the year of Tekes' project funding decision	PATENT_VALID	4.59	45.61
Dummy variable that gets value 1 if firm's project is part of Tekes technology program, 0 otherwise	TECH_PROGRAM	0.23	0.42
Dummy variable that gets value 1 if part of the firm's Tekes project funding is allocated to university or research institute, 0 otherwise.	RES_ORG_COLLAB	0.31	0.46
Dummy variable that gets value 1 part of the large firm's Tekes project funding is allocated to SMS firm(s), 0 otherwise.	SMS_COLLAB_LARGE	0.10	0.30
Dummy variable that gets value 1 if business to be generated within the firm's project is new, 0 if it is existing.	NEW_BUSINESS_DMY	0.46	0.50
Dummy variable that gets value 1 if firm exports products or services, 0 otherwise.	EXPORT	0.45	0.50
Dummy variable that gets value 1 if firm is among those 10 companies that have largest number of Tekes financed projects ending 1999-2003, 0 otherwise.	TOP10_FIRM	0.11	0.31
Asiakastieto debt rating class: Excellent: AAA = 6 good+ AA+ = 5 good AA = 4 satisfactory+ A+ = 3 satisfactory A = 2 välttävä B = 1 poor C = 0	RATING_CLASS	4.15	1.48

Firm's return on its total equity (%)	RETURN_EQUITY	4.71	63.76
Log firm's age	AGE	2.42	0.80
Dummy variable that gets value 1 if firm has 10-50 employees and its turnover is max 50 million euros, and 0 otherwise.	MEDIUM	0.12	0.33
Dummy variable that gets value 1 if firm has more than 250 employees and its turnover is over 50 million euros, and 0 otherwise.	LARGE	0.26	0.44

project by three variables: i) the dummy variable that gets value 1 if the planned project is part of a technology program of Tekes and 0 otherwise (the variable TECH_PROGRAM), ii) the dummy variable that gets value 1 if part of the firm's project funding is allocated to a research organization (e.g. university) and 0 otherwise (the variable RES_ORG_COLLAB) and iii) the dummy variable that gets value 1 if part of the large firm's project funding is allocated to the SMS firm and 0 otherwise (the variable SMS_COLLAB_LARGE).

The first dummy variable measures the importance of the firm's participation to the technology programs in the key R&D areas Tekes has selected and within which it allocates money for the companies and research organizations. The primary aim of Tekes technology programs is to facilitate collaboration with research and business on the selected technology fields, and to further accelerate creation and production of innovations on them.[11] The second dummy variable measures whether the applicant firm's planned collaboration with the university or research institute affects to the success of its project application. The third variable is used for investigating whether the large companies' collaboration with the SMS firms has impact on the acceptance of their Tekes project plan. We expect that all three of these dummy variables positively related to the funding decision of Tekes.

[11] "Tekes technology programmes are forums for the exchange of information and networking between companies and research groups. They provide opportunities to carry out ambitious R&D projects and develop business expertise and international cooperation. Technology programmes are a gateway to best researcher groups and innovative R&D companies in Finland. Half of the Tekes funding is channelled through the technology programmes. The programmes are established in strategically important R&D areas that Tekes has identified together with the business community and researchers. A typical programme lasts five years. Tekes generally finances about half of the project costs. The other half comes from companies and research units. Every year companies participate in about 2,500 projects and research universities in about 1,500 projects." (http:// www.Tekes.fi)

Our data comprise information also on whether *the business to be generated* within the planned project is new or existing. We create a dummy variable NEW_BUSINESS that gets value 1 in case of new business and 0 otherwise. Tekes supports firms' research and development activities that are related to the promising entries to the new business areas.

The expected positive long-term export impact of the funded project is one of the decision criteria of Tekes that improves the chances of the firms targeting their products to the international markets to receive funding. We use as a rough proxy for the potential export impact the dummy variable EXPORT that takes value 1 if the firm exports products or services and 0 otherwise. Our hypothesis is that those firms that already have established export channels can more credibly convince the financer of the positive long-term export impacts of their project, and thus the sign of the estimated coefficient of this variable should be positive.

Tekes also expects that the applicants have *sufficient resources* available to undertake the planned project. Capital constraints are typically limiting the R&D investments of the small and medium sized companies but as a part of Tekes funds are specifically targeted to the SMS firms, the firm size does not seem to be a reasonable measure here. We use, instead, a measure of company's financial strength: the variable RATING_CLASS get values from 0 to 6 according to the debt rating class[12] of the firm from, respectively, "poor"=C to "Excellent"=AAA. This variable controls for the firm's ability to meet its financial obligations. We also measure the firm's profitability by the firm's return on its total equity (the variable RETURN_EQUITY) that is a firm's profit as a percent share of its total shareholder equity. Whether the financially stronger and more profitable firms are favored in the Tekes funding decisions, these variables should have positive estimated coefficients.

It is also possible that some firms have a more advantageous position in the public funding applications procedure due to their greater resources for filing and lobbying the application.

[12] See description of variables in Annex 2 for detailed information concerning this debt classification.

We control for the firm size by the two dummy variables MEDIUM and LARGE that get value 1, respectively, when the firm is medium sized and large, and 0 otherwise.

The industrial and regional technology policies may affect the distribution of the public funds across the industrial sectors and geographical locations, and via this the chances of an individual company to obtain public R&D support. In Finland, the regional technology and science policy has promoted equality across regions, whereas the Tekes technology policy has favored certain technology areas resulting in an unequal distribution of public R&D support across industries. We therefore also control for the industry and location of the companies that have applied for Tekes R&D finance.

As the firm- and project-specific factors that determine whether the firm's R&D funding application to Tekes is accepted or rejected are of interest as such, we present here the estimation results of the probit model for Tekes' acceptance of a firm's R&D project funding applications (Table 4).

Table 4. The estimation results of the probit model for Tekes' acceptance of a firm's project funding application

	Dependent variable: dummy variable that gets value 1 if firm's Tekes finance application was accepted, 0 otherwise.
Constant	0.21 (0.34)
PATENTS_VALID	0.01 (1.54)
TECH_PROGRAM	0.77 (4.01)
RES_ORG_COLLAB	0.71 (4.84)
NEW_BUSINESS_DMY	-0.11 (-0.66)
SMS_COLLAB_LARGE	0.45 (2.04)
EXPORT	-0.01 (-0.05)
RATING_CLASS	0.20 (3.18)

RETURN_CAPITAL	0.00 (1.26)
MEDIUM	-0.07 (-0.26)
LARGE	-0.25 (-0.91)
+ industry dummies + regional dummies	
Number of observations	1224
Log-likelihood	-48.34
Share of correctly classified observations	98.7%

T-values that are calculated by using the estimated robust firm cluster-specific standard errors are reported in the parantheses.

The number of a firm's valid patents at the year of Tekes funding decision is positive but it does not appear statistically significant after controlling for the project- and firm-specific factors. It seems that the best predictors of whether or not a firm receives Tekes finance are, consistent to the publicly available selection criteria, those factors that measure the order of magnitude of a firm's collaboration with the external parties within the planned project. The dummy variables for the firm's planned participation to one of the Tekes technology programs, its university/research institute collaboration and the large firm's collaboration with the SMS firms are all positively and statistically significantly related to the firm's success in obtaining funds from Tekes. The project applications concerning new business areas are generally not more favored than the projects targeted to the firm's existing business areas. The estimated coefficient of the variable RATING_CLASS is positive and highly significant implying that Tekes tends to provide R&D funding for the financially stronger applicants.

Overall the above estimation results hint that the Tekes officers making the finance decisions of the entrepreneurial R&D projects are acting consistently with the published selection criteria of Tekes.

3.2 Innovation performance

We measure firms' innovation performance using two different variables: i) the dummy variable PATENT_DMY that gets value 1 if the firm filed a patent application at a given year and 0 otherwise, and ii) the patent count variable PATENT_COUNT which is the number of patent applications a firm has filed at year t. We estimate the patent production function that links the innovation performance variable to the firm's R&D spending and various other firm- and industry-specific characteristics that may affect the firm's propensity to innovate and file patent applications.

Our major interest is whether and via which channels Tekes funding affects the firms' patenting behavior. We measure the order of magnitude of Tekes funding by the variable TEKES_RD that is the (log) total annual R&D funding (including both subsidies and loans) that the firm has obtained from Tekes. We also test the significance of the dummy variable TEKES_PROJ that gets value 1 during those years a firm has received funding from Tekes, and 0 otherwise.

We use the following set of explanatory variables while estimating the patent production function. The firm's own annual R&D expenditures control for the impact of the total R&D input on the firm's innovation performance. The variable RD is log firm's annual R&D expenditures the firm has reported in the project follow-up forms returned to Tekes. The type of the firm's project, whether it is a R&D project or merely focused on development activities, is controlled by the dummy variable RD_project.

R&D collaboration is generally expected to stimulate innovation via spillovers. We control for the firm's participation to the collaboration enhancing technology program(s) of Tekes by the variable TECH_PROGRAM. We also use the dummy variables RES_ORG_COLLAB and SMS_COLLAB_LARGE, respectively, to control for the firm's research collaboration

with the universities or research institutes and, in case of the large firms, with the small and medium size companies. If the firm has multiple projects during the year, these dummy variables take value 1 if any of the firm's projects fulfills the criteria of the variable getting value 1.

The firm size and age may affect to a firm's propensity to produce innovations and patent them. On the one hand, the empirical industrial organizational literature suggests that the small markets entrants tend to produce relatively more innovations than the old incumbent companies (see, e.g, Czarnitzki and Kraft, 2004; Lerner, 1997). The I.O. theory explains the greater incentives of the market entrants to innovate arising from the tendency of new (radical) technologies to cannibalize incumbent firms' profit streams from old technologies, unlike in case of the entrants having no profits yet, and make thus the incumbents more reluctant to innovate than the entrants. The organizational economics literature supports the same conclusion with the different argumentation: Holmström (1989) states that the large companies may generally not succeed in producing drastic innovations for the reasons relating to their inherent bureaucracy and capital market monitoring. Managers may favor less risky R&D projects with faster payback as they result in increased observed performance of the managers. Further, the concern for reputation may make the managers to acting more cautiously and not to undertake risky projects. However, large companies may patent more innovations due to the greater resources they have available for expensive and time-taking patenting procedures. Also, the older companies may have established routines for patenting – that the small market entrants lack – and may then be more likely to file patent applications.

We also control for the type of business for which the firm has applied Tekes funding, new or existing, by the NEW_BUSINESS dummy variable. As discussed above, the industrial organization literature suggests that the new market entrants tend to be more innovative than the incumbent companies. This variable differs from the variable capturing the firm's age as

most of the companies exploring new business areas within their Tekes financed project are incumbent companies, and only about 6% of them are start-up companies.[13]

The dummy variable TOP10_FIRM controls for the ten largest obtainers of Tekes project funds; it gets value 1 if the firm is among the top ten receivers of Tekes funding among the sampled projects and 0 otherwise. Both technological opportunities reflecting the firm's propensity to create patentable new technologies and the firm's propensity to patent innovations vary by industries. We use the industry dummy variables to control for this industry-specific variation. The regional dummy variables are added to control for possible regional differences in the firms' innovation potential.

We use the Heckman sample selection procedure to control for the potential sample selection bias. The first stage of the model estimates the probit model for the variable TEKES_FUND, i.e. it explains whether the firm's project proposal to Tekes was accepted and the R&D support granted or not. The second stage of the estimation concerns the probit model for the variable PATENT_DMY that includes the Heckman sample correction term, the Inverse Mill's ratio, controlling for the potential sample selection bias. In the case of the patent count variable, we estimate the negative binomial model with the Heckman sample selection procedure. These estimations use the pooled data, with the specification of standard errors to be robust to both heteroscedasticity and serial correlation. As we are particularly interested in the differences in the innovative performance of the firms before they obtained public R&D support and after they received Tekes finance, we include only observations from the years before and during the firm's Tekes financed projects to the estimated model.

We may first note that the Inverse Mill's ratio is not statistically significant in any of the estimated equations. The non-random sample selection seems not cause problem in the

[13] The average age of the firms that began a Tekes project targeted to a new business area was about 8 at the first year of the project.

Table 5. The estimation results of the models for firm's innovation performance

Variables	Heckman probit model with sample selection Dependent variable: PAT_DMY	Heckman probit model with sample selection Dependent variable: PAT_DMY	Heckman negative binomial model with sample selection Dependent variable: PAT_COUNT	Heckman negative binomial model with sample selection Dependent variable: PAT_COUNT
Constant	-2.30 (-5.19)	-1.64 (-3.67)	-3.46 (-5.67)	-3.20 (-5.50)
RD	0.17 (4.33)	0.17 (4.38)	0.45 (7.90)	0.44 (7.78)
TEKES_RD	0.03 (1.65)		-0.02 (-1.21)	
RD_PROJECT	-0.31 (-1.08)	0.31 (1.01)	0.30 (0.73)	0.30 (0.72)
TECH_PROGRAM	-0.14 (-0.78)	-0.31 (-1.06)	0.29 (1.23)	0.33 (1.37)
RES_ORG_COLLAB	-0.28 (-1.50)	-0.11 (-0.60)	-0.10 (-0.34)	-0.06 (-0.20)
SMS_COLLAB_LARGE	0.32 (1.09)	-0.21 (-1.10)	1.32 (3.51)	1.33 (3.55)
NEW_BUSINESS_DMY	0.41 (2.82)	0.36 (1.22)	0.76 (3.72)	0.78 (3.82)
EXPORT	0.27 (1.94)	0.44 (2.98)	0.56 (0.21)	0.56 (2.60)
TOP10FIRM	0.93 (2.60)	0.27 (1.95)	0.94 (2.25)	0.91 (2.18)
AGE	0.05 (0.72)	0.95 (2.63)	0.05 (0.72)	-0.02 (-0.25)
MEDIUM	-0.15 (-0.65)	0.05 (0.69)	-0.15 (-0.65)	0.39 (1.39)
LARGE	-0.03 (-0.10)	-0.14 (-0.62)	-0.03 (-0.10)	-1.19 (-2.30)
Inverse Mill's ratio	0.24 (-0.87)	-0.07 (-0.24)	0.57 (0.41)	0.73 (0.53)
α			2.33 (7.84)	2.32 (7.81)
+ industry dummies + regional dummies + year dummies				
Number of observations	1122	1122	1122	1122
Log-likelihood	-612.55	-580.16	-1224.29	-1223.49

T-values that are calculated by using the estimated robust firm cluster-specific standard errors are reported in the parantheses.The explanatory variables of the probit model for Tekes finance decisions reported in Table 3 are used as the instruments for the endogenous Tekes funding variables.

specified empirical equation. However, our descriptive analysis was pointing that the top ten receivers of Tekes funding are outliers, large companies that are patenting clearly more than other sampled companies that need to be controlled for. Indeed, the variable TOP10FIRM is significantly explaining variation in the dependent variables in all cases.

The firm's own R&D expenditures appear, consistent with the economic theory and the previous empirical studies on the patent-R&D relationship, as a statistically significant predictor of both the firm's propensity to file patent applications and the number of filed patent applications in all of the estimated equations. The estimation results confirm the conclusions of the descriptive analysis of the data: Tekes funding is not statistically significantly related to the number of patent applications filed by the firms. The variable TEKES_RD is, however, weakly significant (at p=0.10) in the probit equation. It is notable that this variable would appear statistically significant if we wouldn't control for the top ten companies receiving support for their R&D projects during the sampled time period.

Though the direct relationship between Tekes funding and the firms' patenting activities seems weak, we find evidence that some characteristics of the Tekes funded projects relate positively and statistically significantly to the firm's innovation performance. Those companies that have obtained Tekes support for the R&D activities involving new business areas to the firm are more likely to apply for patents and also tend to file more patent applications than other companies. The estimation results of the selection equation concerning the factors determining Tekes project approval decision indicate that the projects targeted to new business areas are not more often accepted by Tekes than others, but it seems that those funded have been successful in terms of innovation. One explanation for this finding arises from the economic literature of innovation: there is evidence that the firms entering to the new market areas tend to innovate more than the incumbent (market leader) companies.

Certain collaboration within the Tekes funded projects seems to also matter: the large firms' collaborating with the SMS firms tend to file more patent applications than others. The empirical economic literature has found that the small firms produce a disproportionate shahre of the (radical) innovations but that the large incumbent firms have the advantage of greater resources, and often also experience, to acquire costly patents. This empirical finding may thus not only reflect the benefits of R&D collaboration, arising from knowledge spillovers, between the small and large firms but it may also indicate that the SMS originated innovations are more often patented when there is a large R&D partner with the experience and resources to file patent applications.

4. Conclusions

The heterogeneity in the performance of the Tekes financed firms seems too large for detecting any significant direct relationship between the financial support of Tekes and the firms' innovation output. The firms that were obtaining the public R&D support were not performing significantly better, on average, than others. However, we find evidence that the R&D finance from Tekes has substantially influenced the innovation output of the firms that have undertaken certain types of innovations activities. Particularly, Tekes funding of the R&D projects targeted in the new business areas seems successful.

Certain types of collaboration seem to also generate better entrepreneurial performance in terms of innovation. Those large firms that have more intensively collaborated with the small and medium sized firm partners within their Tekes funded projects have filed more patent applications than other companies. This observed effect may reflect knowledge spillovers arising from the collaboration between the small and large firms but it may also indicate that innovations originating from the SMS firms are more often patented when there is a large

R&D partner with the experience of patenting procedure and the resources to file patent applications.

A positive relationship between the firm's R&D expenditures and innovation output is consistent with the empirical findings of the mainstream literature. As the previous empirical studies using the Finnish firm-level data hint that Tekes funding has increased the firms' own R&D spending, it is possible that Tekes funding has contributed firms' innovation output indirectly via the stimulation of the funded firm's R&D.

Our data, however, show that few large companies - with substantially higher R&D expenditures and innovation output than average firms before receiving public R&D support - have obtained a disproportionate share of the public R&D funding, and if these outlier observations are not taken into account in the empirical analysis, the conclusions regarding the effects of the public R&D funding may be overly optimistic. This also leads to a question whether the socio-economic benefits arising from the chosen allocation of public funding to R&D justifies its costs. The future research might get closer to answering this question if there were sufficiently reliable measures of the values of produced innovations – not just counts - and the order of magnitude of spillovers, particularly arising from the largest subsidized companies, available for an empirical investigation.

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Annex 1: Number of firms with project beginning and ending years

Beginning year Ending year	1999 or before	2000	2001	2002	2003	Total
1999	241	0	0	0	0	241
2000	248	2	0	0	0	250
2001	238	52	3	0	0	293
2002	149	83	43	3	0	278
2003	98	47	63	32	2	242
Total	974	184	109	35	2	1304

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