Tanja Tanayama

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To Siiri and Vilma

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Tuusula, June 2007

Tanja Tanayama

Abstract

This dissertation consists of four essays on the functioning of public research and development (R&D) subsidy programs. The topic of the first three essays is the selection process, also referred to as the participation process. The participation process consists of two decision problems: firms have to decide on whether to apply for a subsidy or not and the government agency allocating subsides has to decide on the subsidy. In the first essay we develop a fully structural model describing the two decision problems in the context of firms that engage in R&D to maximize profits and a public agency that decides on R&D subsidies to maximize its benefits. In the second and the third essay I examine more in detail the application and the allocation decisions respectively. In the fourth essay I take a different angle and develop a theoretical model to examine whether R&D subsidies can alleviate financial constraints and through which channels this effect comes from.

In the first essay we develop a new structural method to estimate the expected returns to R&D, their distribution, and their determinants, including the effect of possible subsidies. First a model of continuous optimal treatment with outcome heterogeneity is developed, where the treatment outcome depends on the applicant's investment. The model takes into account application costs, and isolates the effect of the treatment on the public agency running the treatment program. Under the assumption of a welfare-maximizing agency, the model generates expected general equilibrium treatment effects and social returns to R&D. Then the model is taken to project level data from the Finnish Funding Agency for Technology and Innovation (Tekes) granting process of R&D subsidies. The findings indicate that expected returns on R&D are high, their distribution skew, and treatment effect heterogeneity substantial. Agency's utility not appropriated by the applicant is linear in R&D. The median increase in this expected agency specific utility from subsidies is 44 000 euros. Ignoring application costs severely biases the estimated treatment effects and returns upwards.

In the second essay I analyze the application for R&D subsidies. Finnish firm-level data on applicants and potential applicants is used to characterize the application behavior of firms. In addition to analyzing the characteristics underlying application for R&D subsidies, also the use of count data models in modeling the application for R&D subsidies is examined. The findings suggest that firms that are the most likely to have eligible projects, are also aware of the R&D subsidy program. The results also suggest that the opportunity cost of applying is lower for firms quite at the beginning of their life cycle. In addition the results provide evidence that external knowledge is important in lowering the application cost. Industry level heterogeneity in application behavior seems to be related to the application activity of potential applicants rather than the awareness of the program. The model selection exercise indicates that in using a count data framework to model the application behavior it is important to

take into account both unobserved heterogeneity and excess zeros.

The third essay examines the allocation rule of the public agency. R&D subsidies to business sector constitute a selective policy tool to encourage private R&D activities. The efficiency and functioning of this tool depends on how the public agency allocates subsidies. The program under scrutiny is that of Tekes. The results indicate that in general Tekes adheres to the stated funding policy and criteria. The technological content of a project proposal and risks related to the implementation of the project are important in determining both whether an application is accepted and the subsidy-level. In addition being a small and medium size company increases the acceptance probability. Also the extent of collaboration matters. All these findings are in line with the stated funding policy and criteria. However, Tekes seems to be averse to risks related to the commercial potential of the project proposal. It can be questioned whether this observation is in line with the stated objectives.

The fourth essay analyzes the role of R&D subsidies in reducing possible adverse selection based financing constraints related to innovation financing. Asymmetric information about the quality of an innovation project between the entrepreneur and the financier leads to a higher cost of external than internal capital, creating a funding gap. This funding gap may prevent especially small and new technology-based firms from undertaking economically viable innovation projects. Results indicate that under certain conditions, public R&D subsidies can reduce these financing constraints. Two different channels generate this effect. First, the subsidy itself reduces the capital costs related to the innovation projects by reducing the amount of external capital required. Second and more important, the observation that an entrepreneur has received a subsidy for an innovation project provides an informative signal to the market-based financier.

Keywords: R&D subsidy, participation process, structural econometrics, treatment effects, count data models, adverse selection, financial constraints.

Contents

I Introduction

This dissertation is about public subsidies to industrial research and development (R&D) activities. Public R&D subsidies constitute one of the largest form of industrial subsidies in OECD countries.[1] Moreover, the relative importance of R&D activities as purpose of industrial subsidies has increased. Lee (2002) documents that at the end of 1990's countries like US, Canada and Japan directed over 40 percent of all industrial subsidies to R&D. Within EU, countries with high priority to R&D were Austria, Belgium, Denmark, Finland, France, the Netherlands and Sweden, Finland being the country devoting the largest share of subsidies to R&D - over 30 percent. These figures indicate that subsidies to industrial R&D constitute an important element of technology policy in industrialized countries. OECD statistics reveal that on average governments finance about 8 percent of the overall financing of business enterprise expenditure on R&D within OECD countries (OECD, 2006). Clearly there seems to be a common belief that government intervention in the form subsidies to industrial R&D is warranted. Economics has contributed to the emergence of this belief.

1 The economic motive for policies to promote private R&D investments

The notion of technological change started to gain firmer footing in economic literature in 1950's when several studies suggested that the growth in output in U.S. stemmed largely from technical change (Fabricant, 1954, Abramovitz, 1956, Kendrick, 1956 and Solow, 1957).[2] In the neo-classical growth literature especially the contribution of Solow (1956) was important in highlighting the role of technological change in growth. However, these neo-classical growth models considered technological change as exogenous to the economic system and it was explained as a residual that could not be assigned to conventional inputs. This failure of neo-classical models to explain the process of technological change lead to an inquiry into the determinants of technological change. This

[1] Lee (2002) documents that industrial subsidies in general account for 20 to 30 percent of all OECD support to various economic sectors and virtually all OECD countries provide some sort of industrial support.

[2] Griliches (1996) provides a detailed historical survey.

inquiry generated a body of economic literature consisting of both theoretical and empirical work focusing on the role and sources of technological change within the economic system.[3]

From the point of view of public subsidies to industrial R&D, this literature generated three important observations that are nowadays widely accepted.

1. Knowledge is a key determinant of technological change and it has some public good properties (Arrow, 1962).
2. Social rates of return to R&D may be substantially higher than private rates of return (Griliches, 1958, 1964, 1979; Arrow, 1962).
3. Knowledge creation activities of profit maximizing firms by deliberate investments in R&D activities are crucial to technological change (Griliches, 1957, Mansfield, 1968, Romer, 1990, Grossman and Helpman, 1991 and Aghion and Howitt, 1992).

The first point stresses the central role of knowledge creation activities in technological change and establishes the link between growth and knowledge creation. In addition it highlights the special characteristics of knowledge as a good, namely that knowledge constitutes a non-rival and only partially excludable good. The second point highlights that knowledge creation is associated with positive externalities, spillovers and consumer surplus, to the rest of the society.[4] Because of these externalities, there may be, from a social point of view, underinvestment in knowledge creation activities. The third point stresses the role of firms' R&D investments, arising from profit maximization, as a crucial input into the process of technological change. OECD (2006) statistics indicate that industrial sector finances on average over 60 percent of gross domestic expenditure on R&D within OECD countries. Together these observations raise the question that given the important role of firms in the process of technological change, does the market economy provide adequate incentives for firms to invest in R&D? There is quite a common agreement among economists that the answer to this question is no.

[3] Shaw (1992), Grossman and Helpman (1994) and Romer (1994) review developments in growth theory and summaries of the empirical literature include Griliches (1992, 1996) and Nadiri (1993).

[4] There is a vast econometric literature analyzing the presence of positive spillovers (for surveys see e.g. Griliches, 1992; Nadiri, 1993; Hall, 1996; Jaffe, 1996). The results of this literature suggest that positive spillovers are present and social rates of return are likely to be considerably higher than the private ones (Klette et al., 2000).

The main economic rationale arguing that market economy fails to provide sufficient incentives for firms to engage in R&D activities relies on the above first two points. The fact that the output of investments in R&D, namely knowledge, is non-rival and only partially excludable implies that firms are unable to appropriate all the benefits from their investments, which reduces their incentives to invest in R&D. At the same time the positive externalities associated with firms' knowledge creation activities imply that social benefits from firm's R&D activities are higher than the benefits accruing to the firm. This suggests that left alone firms' R&D investments are likely to remain below the social optimum. From a policy point of view this argument results in a dilemma: on one hand a policy should enhance incentives for the socially efficient production of knowledge, and on the other hand the policy should encourage incentives for the socially efficient diffusion of knowledge (Branstetter and Sakakibara, 1998)

In addition, the economic literature has highlighted that uncertainty related to knowledge production activities may further undermine firms' R&D investments. There are two different arguments why uncertainty may lead to reduction in firms' R&D investments. The first one is related to possible financial constraints. The argument states that informational problems created by uncertainty, more specifically asymmetric information about the quality of an innovation project between entrepreneurs and financiers, leads to a higher cost of external than internal capital (Leland and Pyle, 1977; Myers and Majluf, 1984; Hubbard, 1998; Alam and Walton, 1995). In the absence of internal funding this may prevent firms from undertaking economically viable R&D projects. The second argument is based on the assumption that in general firms are risk-averse, which leads to sub-optimal allocation of risk meaning that there will be discrimination against risky (highly uncertain) projects (Arrow, 1962). In other words, from social point of view firms' preference for safer innovation projects gives rise to a loss of welfare. This argument is less emphasized in the economic literature, but seems to be underlying, at least implicitly, several R&D subsidy programs (e.g. the Advanced Technology Program in U.S. and the R&D subsidy program of Tekes in Finland).

The identified market failures related to the knowledge creation activities of firms have generated a vast array of policy instruments designed to affect firms' investment in R&D. Griffith (2000) differentiates between direct and indirect policies. Indirect policies do influence the decisions of firms to engage in R&D, but the primary reason to design these policies is seldom related to R&D considerations. Examples of indirect policies are general taxation policy, macroeconomic policy, education and training policy, competition policy and regulations.[5] Direct policies are in turn especially designed to influence firms' R&D activities.

The main direct policies include direct funding of firms' R&D activities, tax credits for R&D and intellectual property rights. Intellectual property rights are designed to improve the appropriability of knowledge and in that way increase the incentives for R&D (see e.g. Scotchmer, 2004), tax reliefs in turn aim for the same by reducing the cost of R&D (see e.g. Quellec and van Pottelsberghe, 2000; Hall and Van Reenen, 2000). Direct funding covers public procurement and direct R&D subsidies, of which public procurement is mainly related to the development of technologies that for one reason or another are considered especially important to the society (for example technologies related to defence, health-care or aerospace). In this dissertation the focus is purely on direct R&D subsidies.

As the discussion in the beginning of this section indicated, R&D subsidy programs constitute a widely used policy instrument to encourage the investments of firms in R&D. Jaffe (2002) provides a stylized description how these R&D subsidy programs work in general. The basic idea is that first government budget money is allocated to a program that, depending on the design, targets more or less specified R&D activities of firms. Second, firms apply for the money by submitting a proposal for an R&D project. Third, the agency running the program evaluates and ranks the projects according to some predefined criteria (or solicits external evaluation of the projects). Fourth, the agency decides which proposals to fund and how big a subsidy to grant. The decision is based on official funding criteria, but also other issues may affect the decision. The basic idea is that by sharing the costs of R&D, subsidy programs increase firms' incentives to engage in knowledge creation. In addition, these programs are not available for all, but they are directed to specific kind of activities, industries, technologies or firm groups. The targeting can be more or less restrictive. Directing public money to specific targets reflects the idea that the gap between social and private benefits of R&D may differ, and the goal is to channel funding to its most productive use, i.e. where the gap is the widest. Moreover, additional aspects are often embedded in the design of R&D subsidy

[5] Competition policy and many regulations are to a certain extent borderline cases, since R&D considerations are more explicitly incorporated in the design compared to many other indirect policies, technical standards provide one example. Another example of a borderline case could be public efforts to increase the functioning of financial markets (e.g. support to venture capital markets) in order to reduce possible financial constraints.

programs like emphasis on enhancing collaboration. Support to collaborative activities attempts to alleviate the trade-off between providing incentives to the production of new knowledge and its diffusion within the economy.

This dissertation is built around the R&D subsidy program of the Finnish Funding Agency of Technology and Innovation. The design of this program resembles closely to the stylized description of Jaffe. Especially the second essay describes this program in detail. Some other examples of related R&D subsidy programs include the Advanced Technology Program (ATP)[6] and the Small Business Innovation Research (SBIR) Program[7] in U.S., R&D subsidy programs in Israel[8], R&D grants allocated by the Federal Ministry of Research and Education in Germany[9], and R&D subsidy program of the Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT) in Belgium[10] .

Despite the common perception that market failures related to the production of knowledge are present, the issue of whether government intervention can improve the situation is controversial. This holds also for public R&D subsidy programs. Jaffe (2002) describes the related political discussion as follows:

> *Much of the political debate surrounding such programmes remains at the level of ideology: Opponents question at a conceptual level how government programmes can pick 'winners and losers' without interfering in market processes to an undesirable extent......... Supporters rely on the already mentioned theoretical case for inadequate private incentives.*

There is an increasing political urge to get plausible evidence about the functioning and effectiveness of these programs.

2 R&D subsidy programs in the economic literature

One response to the call of plausible evidence is a growing literature on quantitative evaluations of the effects of public R&D subsidies on private R&D activities.

[6]See http://www.atp.nist.gov/index.html, accessed on 20 November, 2006.
[7]See http://www.sba.gov/SBIR/indexsbir-sttr.html, accessed on 20 November, 2006.
[8]Trajtenberg (2001) provides a detailed summary of R&D subsidy programs in Israel.
[9]See http://www.bmbf.de/en/index.php, accessed on 20 November, 2006.
[10]See http://www.iwt.be/iwt_engels/,accessed on 20 November, 2006.

Majority of the econometric evaluation studies have focused on the issue of additionality: whether public R&D subsidies complement or crowed out private R&D investments (David, Hall, and Toole, 2000; and Garcia-Quevedo, 2004 survey the literature, more recent studies include Lach, 2002; Almus and Czarnitzki, 2003; Duguet, 2003; Ali-Yrkkö, 2004; Aerts and Schmidt, 2006). These additionality studies attempt to identify the effect of R&D subsidies on firms' R&D investment. In addition there are some econometric studies analyzing the effect of public R&D subsidies on some performance indicator. Of the studies covered by the survey of Klette et al. (2000) Irwin and Klenow (1996) as well as Klette and Moen (1998) consider several performance indicators like productivity and growth, Griliches and Regev (1998) focus on total factor productivity growth, Lerner (1996) examines the effect of awards on growth and Branstetter and Sakakibara (1998) examines the effect on patenting. One of the conclusions drawn from these econometric evaluations is that based on them it is difficult to end up with a conclusive answers about the effects of R&D subsidy programs.

Several arguments have been proposed to explain the difficulty to draw definitive conclusions. Both Klette et al. (2000) and David et al. (2000) raise the question of whether the econometric setups have been adequately specified. Of special concern is the difficulty of taking into account the possible selection bias related to the funding process. The main counter factual of interest in evaluating R&D subsidy programs is what would have been the performance of the participants in the absence of the program. Often this question is addressed by comparing the difference in performance between the participants and a group of non-participants. However, the performance of non-participants may differ systematically from what the outcomes of subsidized participants would have been in the absence of subsidies.[11] This selection bias makes it difficult to identify the effect of a public subsidy. In addition to systematic differences between the two groups, Klette et al. discuss an additional complication created by spillovers. Because of spillovers, also the non-participants may be affected by the subsidy program invalidating further the use of a control group in answering the counter factual. The issue of spillovers is especially important in analyzing the effects of R&D subsidy programs as spillovers are precisely one of the main justification for the existence of these programs. Given that the benefits of R&D subsidies and R&D investments in general are likely to be heterogeneous and skewed across firms, Klette et al. also raise the question of whether the main

[11] Heckman, Ichimura, Smith and Todd (1998) provide an extensive treatment of the selection bias.

parameter of interest is indeed the average impact. David et al. in turn question to what extent it makes sense to try to end up with the right answer, since there are considerable differences in the design and institutional setting of different R&D subsidy programs.

There is relatively scant theoretical literature related to R&D subsidies. Strategic trade policy literature has focused on analyzing optimal (investment) subsidies in different settings of strategic interdependencies between firms in an open economy context. Spencer and Brander (1983) set the ground by analyzing how R&D subsidies affect the strategic interplay between a domestic and a foreign firm when firms invest in cost-reducing R&D in an oligopolistic market. They found that in their setting the optimal subsidy is positive and the role of subsidies is to alter the actions available to the domestic firm such that the domestic firm earns higher profit net of the subsidy. The setup of Spencer and Brander has later been altered to incorporate Bertrand competition instead of Cournot competition, market-expanding instead of cost-reducing R&D, uncertainty in the cost-reducing effect of R&D investment and spillovers.[12] Many of these settings considered provide evidence in favor of R&D (investment) subsidies. In addition there are some studies analyzing optimal subsidies in the presence of other policies like patent policy, subsidies for output and policies toward R&D collaboration (Stenbacka and Tombak (1998) study the last-mentioned setting and provide references to other studies).

Another branch of theoretical literature is the endogenous growth literature that analyzes the effect of R&D subsidies on long-run growth. Papers by Romer (1990), Segerström et al. (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) all established that in the presence of increasing returns to scale and horizontal innovation (entirely new products) subsidies encourage firms to devote more resources to R&D activities and as a result increase the long-run growth rate. Howitt (1999) shows that the same result can apply even in the absence of increasing returns to scale when firms engage both in horizontal and vertical (improvements in the quality of existing products) R&D activities. Segerström (2000) presents a generalized version of the Howitt's model and finds that the effect of subsidies on long-run growth rate can be either positive or negative.

The theoretical literature examining optimal R&D subsidies is important in highlighting what kind of broader economic consequences R&D subsidies

[12]For surveys of the literature see Brander (1995) and Leahy and Neary (2001).

may have in different economic settings. However, they fail to provide clear conclusions about the effectiveness and functioning of R&D subsidy programs. One reason for this is that these studies rely on specific assumptions about how R&D subsidies affect firms' investment in R&D and what kind of outputs firms generate with this investment through their R&D activities. What is missing is an understanding of whether and under which circumstances these assumptions hold: through which channels R&D subsidies affect the behavior of firms and what kind of effects could be expected under different circumstances at the firm level. The few examples of papers focusing on the mechanisms by which the firm-level effects of R&D subsidies can arise include those by Klette and Moen (1998) and Lach and Sauer (2001). The empirical results of Klette and Moen suggest that the long run effects of R&D subsidies are positive, i.e. temporary R&D subsidies increase firms' R&D investment also in the long run. Inspired by this finding they develop a theoretical model in which learning-by-doing generates positive feedback loops explaining the positive long run effects of temporary R&D subsidies. Lach and Sauer in turn develop a model of the process of R&D within firm and use this model to analyze the mechanism by which R&D subsidies may either increase or decrease firm's own R&D investments.

All in all the existing literature, both theoretical and empirical, suggest that there is a need for thorough understanding about the functioning of R&D subsidy programs at the firm level. The theoretical literature has mainly assumed specific firm-level effects of R&D subsidies. The empirical literature, in turn, has focused on establishing the link between subsidies and firm's R&D investments or performance, but it has failed to provide conclusive answers. One possible reason for the ambiguity is that the channels through which these effects are generated and the details of how R&D subsidy programs actually function are not adequately considered. Especially the need for structural models explaining the different channels of influence and the underlying decision-making problems has been highlighted (David and Hall, 2000; Lach and Sauer, 2001). A more micro-oriented understanding of R&D subsidy programs is needed. This dissertation consists of four essays, all of which build on this gap in the literature.

3 Overview of the essays

An important part of the mechanism by which the effects of R&D subsidies arise is the process that determines the allocation of R&D subsidies. The topic of the first three essays is this selection process, also referred to as the participation process. The participation process consists of two important decision problems: firms have to decide on whether to apply for a subsidy or not and the government agency allocating subsides has to decide on the subsidy. In the first essay we develop a fully structural model describing the two decision problems in the context of firms that engage in R&D to maximize profits and a public agency that decides on R&D subsidies to maximize social benefits. In the second and the third essays I examine more in detail the application and the allocation decisions respectively. In the fourth essay I take a separate route and develop a theoretical model to examine whether R&D subsidies can alleviate financial constraints and through which channels this effect is generated.

All the empirical work in this dissertation is based on data consisting of two matched datasets. The firm data, covering originally 14 657 Finnish firms, come from Asiakastieto Ltd. Asiakastieto is a for-profit company collecting, standardizing, and selling firm specific quantitative information. The sample is drawn according to the following criteria: the most resent financial statement of the firm in the register is for either 2001 or 2000, firm is a corporation, and the industrial classification of the firm belongs to the manufacturing, computer and related activities, research and development, architectural and engineering activities and related technical consultancy, technical testing and analysis. The data are based on firms' official profit sheet and balance sheet statements, plus other information disclosed by the firms to public registries like the industrial classification, geographical location, number of employees, whether a firm is an exporter or/and an importer, and information related to the ownership of the firm and the board composition. The project level data consists of internal data of Tekes. Originally the data contain all the business sector applications for R&D subsidies Tekes received from January 1st 2000 to June 30th 2002 and consist of detailed information on the project proposal, the applicant firm and the funding decision of Tekes. This original data covers 3512 applications from 2168 firms.

3.1 Structural modeling of R&D subsidy program

The first essay that is joint work with Tuomas Takalo and Otto Toivanen lays the foundation for the whole dissertation and especially for the second and the third essays. Given the importance of R&D subsidies we know surprisingly little about the processes that allocate them. There is a widespread political urge to get plausible evidence about the effectiveness of this policy tool in terms of additionality, productivity and growth, but it seems that this pronounced focus on impact estimates has diverted attention from the issue of allocation. To get reliable evidence of the effectiveness and functioning of a policy tool like R&D subsidies, the participation process determining who is finally granted a subsidy has to be well understood (Heckman and Smith, 2004). The objective of the first essay is to construct and estimate a structural model of the application and selection process into a voluntary treatment program. In other words, we first formulate a model of firms' and public agency's behavior that explains the mechanism by which firms decide on application and the government agency decides on the subsidy level. Then we take our model to project level data from the granting process of R&D subsidies. The work builds on the treatment effects and structural industrial organization literatures.

The institutional setting of the voluntary treatment program under scrutiny, namely an R&D subsidy program, differs from the settings usually considered in the treatment effects literature. As a result, our model contains several ingredients not commonly embedded in the structural treatment effects literature. We model a continuous, optimal treatment with outcome heterogeneity. In our model the treatment outcome is a function of the applicant's investment, which in turn is a function of the received treatment. In addition the model takes into account usually ignored application costs, and isolates the effects of the treatment that are specific to the agency. Under the assumption of a benevolent public agency, our model identifies general equilibrium treatment effects and social returns to R&D. A key benefit of the structural approach is that the model yields economic interpretation of the unobserved (to the econometrician) shocks and all the estimated parameters.

Our model explicitly describes the underlying decision problems and the interaction between the public agency's and the firms' behavior. As a result, once taken to data, the estimates provided by the model yield insights into the expected effects at the time of applying for and grating a subsidy. We identify the project level expected effects of R&D investments and subsidies on private and agency specific benefits. We find that the returns appropriated by the agency but not by the firm are linear in R&D expenditures and positive in expectation for 97% of the firms in our sample. Private returns are very high and their distribution skew, following earlier findings at least since Griliches (1958). Non-applicants' projects generate larger returns on investments, but applicants' and non-applicants' projects generate similar joint rates of return on the subsidy program, defined as the sum of the applicant's and agency's returns divided by the cost of subsidies. We also identify new treatment effects by measuring the effect of treatments on the agency, and by taking into account application costs. We find considerable heterogeneity in all treatment effects. Neglecting application costs causes a significant upward bias. In allocating the subsidies, the agency generally adheres to the publicly announced principles.

3.2 Application for R&D subsidies

In the second essay I take a closer look at the application decision of firms. The objective of this essay is to provide an explorative step toward understanding the application behavior of firms by empirically analyzing the application for R&D subsidies in detail. As mentioned above, the participation process consists of two decisions: an application decision and a granting decision. Potential participants decide whether to apply for a subsidy or not and the government bureaucrats administering R&D subsidies decides to which applicants to grant a subsidy. Often the latter is highlighted. The discussion about the allocation of R&D subsidies has centered on the question of whether the government can identify projects with high social returns that the private sector would not undertake on its own. Little attention is paid to the application behavior of firms. Heckman and Smith (2004) decompose the participation process into five different stages: eligibility, awareness, application, acceptance and enrollment. The main scope of the second essay is to analyze the application stage. Also eligibility and awareness are discussed.

In addition to analyzing the characteristics underlying application for R&D subsidies, I also examine the use of count data models in modeling the application for R&D subsidies. The rich data at hand allows the identification of applicants and non-applicants, but it also contains information on the number of applications a firm has submitted during the observation period. This kind of data calls for a count data model. Given that there is little evidence on how to use count models in modeling application for R&D subsidies, it is not straight forward to decide what kind of a count data model should be used. As a result, various count models are estimated and compared.

The model selection exercise indicates that in using a count data framework to model the application behavior it is important to take into account both unobserved heterogeneity and excess zeros. Ignoring the issue that the sample consists of both non-applicants and potential applicants can distort the results.

The interpretation of several regressors changes under the assumption that the sample is a mixture compared to an analysis conducted under the assumption that all the observations come from the same data generating process. Considering the sample as a mixture has also intuitive appeal. It provides a statistical method for assessing whether a firm belongs to the group of potential applicants.

The findings suggest that firms that are the most likely to have eligible projects, are also aware of the R&D subsidy program. In other words, the program seems to reach firms that are the most potential participants. However, the way firms engaged in R&D activities and operating in international markets stand out suggests that there may be problems related to the awareness of firms that are not "by definition" among the potential applicants. In addition the results indicate that the opportunity cost of applying is lower for firms quite at the beginning of their life cycle. This result suggests that an important target group of the policy finds the program attractive. The finding that supports the usefulness of external knowledge in lowering application costs indicates that trying the reduce the applications costs firms face, could be important in increasing application activity. Industry level heterogeneity in application behavior seems to be related to the application activity of potential applicants rather than the awareness of the program.

3.3 The subsidy decision

In the third essay I focus on the acceptance stage of the participation process and build on the decision-rule of the government agency that the structural model developed in the first essay yields. Here the aim is not to end up with a structural econometric model to be estimated. Rather the model presented in the first essay serves as a general framework that helps in understanding what the actual estimations of the decision-rule deal with. The scope in this essay is to provide a general discussion on theoretical issues underlying the government agency's allocation of subsidies and examine more in detail how the decision-rule looks like.

Given that R&D subsidies constitute a selective innovation policy tool, a central issue in analyzing the functioning and effectiveness of this tool is how the government allocates subsidies to applicants. Through consistent analysis of the rationales, design and functioning of an R&D subsidy program this essay provides a descriptive account of an R&D subsidy program, but also hopes to provide a more general discussion that is helpful in understanding the operations of R&D subsidy programs and identifying issues that should be carefully scrutinized. The objective is to analyze what matters in the actual allocation decisions of Tekes, whether this is consistent with the publicly stated policy and with the theoretical rationales justifying R&D subsidy policies and finally, whether the decision-making is consistent across different decision-making levels.

The results indicate that by and large the decision-making of Tekes is in line with the publicly stated objectives and funding principles. The identified three key themes of the Tekes R&D subsidy program - technological risk, collaboration and small and medium size enterprises - clearly stand out in the actual decisions. The effect of these factors is especially pronounced on the probability of an application to be accepted. There is, however, one aspect of the stated objectives that does not show up in the actual allocation accordingly. Risk related to the market outcome of the project has negative, if any, effect on the decisions. This may be somewhat in contradiction with the stated objectives of supporting the development of "global success stories" and "sharing the commercial risk related to the project". Decision-making across different decision-making levels seems to be relatively consistent. There is some variation in how some applicant characteristics affect the decisions at various levels, but it is not straightforward to determine whether the differences are due to diverging preferences or due to different firm-samples at different decision-making levels.

3.4 Financial constraints and R&D subsidies

In the fourth essay I depart somewhat from the tightly linked first three essays. The idea is to provide a theoretical account of under which conditions the rationale of financial constraints holds, and whether and through which channels R&D subsidies may reduce financial constraints. The focus is on adverse-selection based financing constraints. Adverse selection is caused by ex-ante informational asymmetries between the entrepreneur and the financier. Asymmetric information about the quality of an innovation project between entrepreneurs and financiers leads to a higher cost of external than internal capital and this may prevent firms from undertaking economically viable innovation projects.

I develop a model of asymmetric information and adverse selection in order to analyze whether R&D subsidy policies can reduce adverse selection based financing constraints. The modeling framework adopted in this paper builds on the seminal model of Holmström and Tirole (1997). Other similar modeling approaches can be found in Repullo and Suarez (2000) and Da Rin, Nicodano and Sembanelli (2005). However, this work differs from the above three in that instead of moral hazard the focus is on adverse selection. Whereas the above three papers highlight the role of monitoring in reducing financing constraints, this study focuses on ex-ante informational asymmetries and the role of screening and signaling in reducing financing constraints. The agents in the model are entrepreneurs, uninformed market-based financiers and a government agency allocating R&D subsidies. Holmström and Tirole (1997) and Repullo and Suarez (2000) identify informed financial intermediaries with banks and Da Rin, Nicodano and Sembanelli (2005) with venture capital firms. The starting point in this paper is that banks are not informed enough and venture capital markets do not function well enough to eliminate financing constraints facing small innovative firms. The point is to analyze whether R&D subsidies could improve the situation and under which circumstances.

The main results indicate that under certain circumstances R&D subsidies can alleviate adverse-selection related financial constraints. This effect is generated through two different channels. First, the subsidy in itself reduces the cost of external capital because the need for market-based financing diminishes. Second and more important, if market-based financiers can observe that a project has received a subsidy from the public agency, the subsidy provides an informative signal about the quality of the R&D project. A subsidy-observation increases the success probability of the project anticipated by the market-based financier. This reduces the cost of external capital for subsidized projects.

These findings highlight that the screening activities related to R&D subsidy policies can have a role of their own in reducing financial constraints. Instead of allocating subsidies, the public agency could have a certification role and yet reduce the financing constraints. Lerner (2002) provides this kind of certification hypothesis when discussing about public venture capital programs. Granting funding strengthens the leverage effect, however.

References

[1] Abramovitz, Moses (1956): Resources and Output Trends in the United States since 1870, *American Economic Review*, 46, 5-23.

[2] Aerts, Kris and Tobias Schmidt (2006): Two for the price of one? On additionality effects of R&D subsidies: A comparison between Flanders and Germany, FETEW Research Report MSI_0607, K.U.Leuven.

[3] Aghion, Philippe and Peter Howitt (1992): A Model of Growth Through Creative Destruction, *Econometrica*, 60, 323-351.

[4] Alam, P. and K. S. Walton (1995): Information Asymmetry and Valuation Effects of Debt Financing, *The Financial Review*, 30, 289-311.

[5] Ali-Yrkkö, Jyrki (2004): Impact of Public R&D Financing on Private R&D - Does Financial Constraint Matter?, ETLA Discussion Papers No. 943.

[6] Almus, Matthias and Dirk Czarnitzki (2003): The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany, *Journal of Business and Economic Statistics*, 21, 226-236.

[7] Arrow, Kenneth J. (1962): Economic Welfare and the Allocation of Resources for Innovation, in Richard Nelson (ed), The rate and direction of inventive activity: Economic and social factors, Princeton University Press, Princeton.

[8] Brander, James A. (1995): Strategic trade policy, in G. Grossman and K. Rogoff (eds), Handbook of International Economics, Vol. 3, North-Holland, Amsterdam.

[9] Branstetter, Lee and Mariko Sakakibara (1998): Japanese research consortia: a microeconometric analysis of industrial policy, *Journal of Industrial Economics*, 46, 207-233.

[10] Da Rin, Marco, Giovanna Nicodano, Alessandro Sembenelli (2005): Public Policy and the Creation of Active Venture Capital Markets, European Central Bank Working Paper Series, No. 430.

[11] David, Paul A. and Bronwyn H. Hall (2000): Heart of darkness: modeling public-private funding interactions inside the R&D black box, *Research Policy*, 29, 1165-1183.

[12] David, Paul A., Bronwyn H. Hall and Andrew A. Toole (2000): Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, *Research Policy*, 29, 497-529.

[13] Duguet, Emmanuel (2004): Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data, Public Economics 0411007, EconWPA

[14] Irwin, Douglas A. and Peter J. Klenow (1996): High-tech R&D subsidies - estimating the effects of SEMATECH, *Journal of International Economics*, 40, 323-344.

[15] Fabricant, Solomon (1954): Economic progress and economic change, 34th Annual Report, NBER, New York.

[16] Garcia-Quevedo, José (2004): Do Public Subsidies Complement Business R&D? A Meta-Analysis of the Econometric Evidence, *Kyklos*, 57, 87-102.

[17] Griffith, Rachel (2000): How important is business R&D for economic growth and should the government subsidise it?, Briefing Note No. 12, The Institute for Fiscal Studies.

[18] Griliches, Zvi (1957): Hybrid Corn: An Exploration in the Economics of Technological Change, Econometrica, 25, 501-522.

[19] Griliches, Zvi (1958): Research Cost and Social Returns: Hybrid Corn and Related Innovations, *Journal of Political Economy*, 66, 419-431.

[20] Griliches, Zvi (1964): Research Expenditures, Education, and the Aggregate Agricultural Production Function, *The American Economic Review*, 54, 961-674.

[21] Griliches, Zvi (1992): The Search for R&D Spillovers, *Scandinavian Journal of Economics*, 94, 29-47.

[22] Griliches, Zvi (1994): Productivity, R&D, and the Data Constraints, *The American Economic Review*, 84, 1-23.

[23] Griliches, Zvi (1996): The Discovery of the Residual: A Historical Note, *Journal of Economic Literature*, XXXIV, 1324-1330.

[24] Griliches, Zvi and Haim Regev (1998): An Econometric Evaluation of High-Tech Policy in Israel, paper presented at the ATP Conference in Washington, D.C., June 1998.

[25] Grossman, Gene M. and Elhanan Helpman (1991): Quality Ladders in the Theory of Growth, *Review of Economic Studies*, 58, 43-61.

[26] - - (1994): Endogenous Innovation in the Theory of Growth, *Journal of Economic Perspectives*, 8, 23-44.

[27] Hall, Bronwyn H. (1996): The private and social returns to research and development, in Smith, B. and C. Barfield (eds.), Technology, R&D and the Economy, Brookings Institution and AEI, Washington DC.

[28] – (2002): The assessment: Technology policy, Oxford Review of Economic Policy, 18, 1-9.

[29] Hall, Bronwyn H. and John Van Reenen (2000): How effective are fiscal incentives for R&D? A review of the evidence, *Research Policy*, 29, 449-469.

[30] Heckman, James J., Hidehiko Ichimura, Jeffrey Smith and Petra Todd (1998): Characterizing Selection Bias Using Experimental Data, *Econometrica*, 66, 1017-1098.

[31] Heckman, James J. and Jeffrey A. Smith (2004): The Determinants of Participation in a Social Program: Evidence from a Prototypical Job Training Program, *Journal of Labor Economics*, 22, 243-298.

[32] Holmström, B. and J. Tirole (1997): Financial Intermediation, Loanable Funds, and the Real Sector, *Quarterly Journal of Economics*, CXII, 663-691.

[33] Howitt, Peter (1999): Steady Endogenous Growth with Population and R&D Inputs Growing, *Journal of Political Economy*, 107, 715-730.

[34] Hubbard, R. G. (1998): Capital-Market Imperfections and Investment, *Journal of Economic Literature*, XXXVI, 193-225.

[35] Jaffe, Adam B. (1996): Economic analysis of research spillovers: Implications for the advanced technology programs. National Institute of Standards and Technology, Report GCR 97-708.

[36] Jaffe, Adam B. (2002): Building programmes evaluation into the design of public research-support programmes, *Oxford Review of Economic Policy*, 18, 22-34.

[37] Klette, Tor Jakob and Jarle Moen (1998): R&D investment responses to R&D subsidies: a theoretical analysis and a microeconometric study, Mimeo, Presented at NBER Summer Institute.

[38] Klette, Tor Jakob, Jarle Moen and Zvi Griliches (2000): Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies, *Research Policy*, 29, 471-495.

[39] Kendrick, John W. (1956): Productivity Trends: Capital and Labor, *Review of Economics and Statistics*, 38, 248-57.

[40] Lach, Saul (2002): Do R&D subsidies stimulate or displace private R&D? Evidence from Israel, *Journal of Industrial Economics*, 4, 369-390.

[41] Lach, Saul and Robert M. Sauer (2001): R&D, Subsidies and Productivity, Mimeo.

[42] Leahy, Dermot and J. Peter Neary (2001): Robust rules for industrial policy in open economies, *Journal of International Trade & Economic Development*, 10, 393-409.

[43] Lee, Frank (2002): OECD Workshop on Environmentally Harmful Subsidies, Paper prepared for the OECD Workshop on Environmentally Harmful Subsidies, 7-8 November 2002, Paris, France.

[44] Leland, H. E. and D. H. Pyle (1977): Informational Asymmetries, Financial Structure, and Financial Intermediation, *The Journal of Finance*, XXXII, 371-387.

[45] Lerner, Joshua (1996): Government as venture capitalist: the long-run impact of the SBIR program, NBER Working Paper, 5753.

[46] - - (2002):When bureaucrats meet entrepreneurs: The design of effective public venture capital programmes, *The Economic Journal*, 112, F73-F84.

[47] Mansfield, Edwin (1968): Industrial Research and Technical Innovation, Norton, New York.

[48] Myers, Stewart C. and Nicholas S. Majluf (1984): Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics*, 13, 187-221.

[49] Nadiri, Ishaq M. (1993): Innovations and Technological Spillovers, NBER Working Paper, 4423.

[50] OECD (2006): Main Science and Technology Indicators (MSTI): 2006/1 edition, OECD, Paris, France.

[51] Quellec, Dominique and Bruno Van Pottelsberghe (2000): The impact of public R&D expenditure on business R&D, STI Working Paper, 2000/4, OECD.

[52] Repullo, Rafael and Javier Suarez (2000): Entrepreneurial moral hazard and bank monitoring: A model of the credit channel, *European Economic Review*, 44, 1931-1950.

[53] Romer, Paul M. (1990): Endogenous Technological Change, *Journal of Political Economy*, 98, 71-102.

[54] Romer, Paul M. (1994): The Origins of Endogenous Growth, *Journal of Economic Perspectives*, 8, 3-22.

[55] Scotchmer, Suzanne (2004): Innovation and Incentives, MIT Press, Cambridge, MA.

[56] Segerström, Paul (2000): The Long-Run Growth Effects of R&D Subsidies, *Journal of Economic Growth*, 5, 277-305.

[57] Segerström, Paul, T Anant and E Dinopoulos (1990): Schumpeterian Model of the Product Life Cycle, *American Economic Review*, 80, 1077-1092.

[58] Shaw, G. K. (1992): Policy Implications of Endogenous Growth Theory, *The Economic Journal*, 102, 611-621.

[59] Solow, Robert M. (1957): Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, 312-320.

[60] Solow, Robert M. (1956): A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, 70, 65-94.

[61] Spencer, Barbara J. and James A. Brander (1983): International R&D Rivalry and Industrial Strategy, *Review of Economic Studies*, 50, 707-722.

[62] Stenbacka, Rune and Mihkel M. Tombak (1998): Technology policy and the organization of R&D, *Journal of Economic Behavior & Organization*, 36, 503-520.

[63] Trajtenberg, Manuel (2001): R&D Policy in Israel, An Overview and Reassessment, In Maryann P. Feldman and Albert N. Link (eds.), Innovation Policy in the Knowledge-Based Economy. Boston: Kluwer Academic Publishers, pp. 409-454.

II Returns to innovation: A structural treatment effect model of R&D subsidies*

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Abstract

We study the returns to R&D, their distribution and their determinants, including the treatment effects of subsidies. We develop a model of continuous optimal treatment with outcome heterogeneity, where the treatment outcome depends on the applicant's investment. The model takes into account application costs, and isolates the effect of the treatment on the public agency running the treatment program. Under the assumption of a welfare-maximizing agency, we identify general equilibrium treatment effects and social returns to R&D. We take our model to project level data from the granting process of R&D subsidies and find that returns on R&D are high, their distribution skew, and treatment effect heterogeneity substantial. Agency's utility not appropriated by the applicant is linear in R&D. The median increase in this agency specific utility from subsidies is 44 000€. Ignoring application costs severely biases the estimated treatment effects and returns upwards.

JEL classification: D21, D6, D73, H20, H83, L59, O30, O31

Keywords: applications, effort, investment, rate of return, R&D, R&D return distribution selection, subsidies, treatment program, treatment effects, welfare

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I Introduction

It has been long recognized that R&D and the distribution of benefits generated by it are crucial for economic growth. The endogenous growth literature has shown that markets typically provide too little R&D and has singled out subsidies to R&D as the main policy tool (e.g. Howitt 1999, Segerstrom 2000). Innovation ranks high on the policy agenda and R&D subsidies have become ubiquitous in practice, being one of the most important tools of innovation policy both in the U.S. and in many European countries.[1]

Some central questions concerning R&D and innovation policy remain however open. For example, our understanding of the social returns to innovation is still limited, nor is there much evidence on the joint distribution of private and social returns to R&D. Little is known on how spillovers are related to the level of R&D at project level. Further, we know surprisingly little about the programs that allocate R&D subsidies. How do the public agencies running programs decide subsidy levels? How do potential applicants decide whether or not to apply? What are the agencies' and the applicants' costs and benefits from the program, and how are they determined? In other words, what are the treatment effects of such a program, and their determinants? To answer these questions we build and estimate a structural model founded on the well-established treatment effects literature and the recent advances in structural industrial organization. Our empirical application uses detailed project level data on R&D investment plans and project characteristics, and R&D subsidy decisions by a government agency.

Methodologically we draw on the extensive treatment effects and labor supply literatures (see e.g. Heckman, LaLonde, and Smith 1999, Blundell and Costa-Dias 2002 and Blundell and MaCurdy 1999 for surveys)[2] and on structural industrial

[1] R&D subsidies are the second largest and fastest growing form of industrial aid in developed countries (Nevo 1998); the U.S. has had several programs (Lerner 1999) and currently spends $1.5 billion a year on one R&D subsidy program alone (the SBIR; see http://www.sba.gov/sbir/indexwhatwedo.html, visited on January 21, 2004) and the EU exempts R&D subsidies from its state aid rules. In Finland where our data originates, R&D subsidies are the most important tool of innovation policy (Georghiu et al. 2003).

[2] The papers in the treatment program literature having a close relation to ours include Bjorklund and Moffitt (1987), Heckman and Robb (1985), Maddala (1983, ch. 9), Manski (2000), and Heckman and Smith (2004) who stress the application and selection decisions, as well as Keane and Wolpin (2001) and Cameron and Taber (2004) who evaluate the effects of tuition subsidies and borrowing constraints. Our paper has a link with the literature on revealed bureaucrat preferences such as McFadden (1975, 1976) who examines bureaucratic decision making in freeway route selection and Heckman, Smith and Taber (1996) who study how the objectives of the office holders affect the selection decisions. Dehejia (2005), like us, models the selection decisions of the public agency. Willis and Rosen's (1979) contribution on education is also in many ways close to our paper. Although the literature on continuous treatment effects and general equilibrium effects is sparse, Heckman (1997) provides theoretical insights in the modeling of continuous treatment effects and Imbens (2000) and Lechner (2001) generalize the standard discrete zero-one

organization work (surveyed by e.g. Reiss and Wolak, 2004).[3] While our objective is to construct and estimate a structural model of the application and selection process into a voluntary treatment program, the institutional setting in our data differs considerably from those usually encountered in the treatment effects literature. As a result, our model contains several ingredients not commonly embedded in the structural treatment effects literature. We model a continuous, optimal treatment with outcome heterogeneity. In our model the treatment outcome is a function of the applicant's investment, which in turn is a function of the received treatment. The model takes into account application costs, and isolates the effects of the treatment that are specific to the agency. Under the assumption of a benevolent public agency, our model identifies general equilibrium treatment effects and social returns to R&D. A key benefit of the structural approach is that the model yields economic interpretation of the unobserved (to the econometrician) shocks and all the estimated parameters. Given our parameterization of the model, it also yields estimation equations that resemble those traditionally used in e.g. the returns to education literature.

Our empirical application relates to the extensive literatures on innovation and the effects R&D subsidies. The existing empirical research has produced indisputable insights into the effects of R&D and R&D subsidies but, in many cases, advances have been hampered by lack of sufficient data. For example, the established but unsettled literature on the R&D-size relationship (see e.g. Cohen 1995) relies almost exclusively on firm level data. The literature on the effects of R&D subsidies is diverse, and methodologically mostly distinct from our approach (see David, Hall, and Toole 2000, and Klette, Møen and Griliches 2000, for surveys). The only paper we know that studies the granting and application side of R&D subsidies is Blanes and Busom (2004). They estimate reduced form models of the joint application and granting decision. Their main finding that firms even in the same industry have different application thresholds both within and between the agencies supports our model and results. Wallsten (2000) and Gonzaléz, Jaumandreau, and Pazó (2005) are rare exceptions in taking a more structural approach to modeling the effects of R&D subsidies. Structural modeling is, however, used more extensively in many other areas of innovation research.[4]

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treatment model to multiple treatment levels. Heckman, Lochner and Taber (1998) and Davidson and Woodbury (1993) in turn suggest procedures to identify general equilibrium treatment effects.

[3] In the structural industrial organization literature, Wolak (1994) and Gagnepain and Ivaldi (2002) are close to ours methodologically.

[4] See, e.g. Pakes (1986) on patent value, Levin and Reiss (1988) on cost-reducing and demand creating R&D, Lanjouw (1998) on patent value and litigation, Eaton and Kortum (2002) on the role of trade in

We have access to rich data from Tekes (the National Technology Agency of Finland), the sole source of R&D subsidies in Finland. Finland provides a neat case for our study because i) innovation policy has long been a central theme in government policy, ii) partly because of successful policy, Finland has particularly rapidly transformed to a technology intensive economy (see e.g. Trajtenberg 2001), and iii) subsidies and, as a result, Tekes, constitute the main innovation policy tool. For example, there are no R&D tax benefits that could jeopardize the policy analysis. The data contain all the subsidy applications, the agency's internal ratings of the applications and its decisions over a two- and half-year period (Jan. 2000 – June 2002). The information on applications is matched to data on over 14 000 Finnish firms that constitute a large proportion of potential applicants.

We find that the returns appropriated by the agency but not by the firm are linear in R&D expenditures and positive in expectation for 97% of the firms in our sample. Private returns are very high and their distribution skew, following earlier findings at least since Griliches (1958). Non-applicants' projects generate larger returns on investments, but applicants' and non-applicants' projects generate similar joint rates of return on the subsidy program, defined as the sum of the applicants' and agency's returns divided by the cost of subsidies. We also identify new treatment effects by measuring the effect of treatments on the agency, and by taking into account application costs. We find considerable heterogeneity in all treatment effects. Neglecting application costs causes a significant upward bias. In allocating the subsidies, the agency generally adheres to the publicly announced principles.

In Section II we present our model. We explain the institutional background and data in Section III and statistical assumptions, identification and estimation in Section IV. Econometric results are reported in Section V and implications of the model in Section VI. Conclusions are in Section VII.

II The model

Our empirical application resembles what Jaffe (2002) calls a 'canonical' research grant program: There is a pool of firms (potential applicants) who have R&D projects that require costly investments. The firms decide whether or not to apply for a subsidy (treatment) program. A subsidy, if received, lowers the marginal cost of their

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diffusing the benefits of new technology, Jovanovic and Eeckhout (2002) on the impact of technological spillovers on the firm size distribution, and Petrin (2002) on the welfare effects of new products.

investment. The program is run by a public agency whose objective function includes the firms' utility as an argument. The agency screens and evaluates the project proposals and then decides how large subsidy (treatment), if any, to give to each actual applicant. Finally, all firms – those that did not apply for a subsidy, those that did but were rejected and the applicants that received a subsidy - maximize profits by choosing their R&D investments.[5]

We model the subsidy program as a four-stage game of incomplete information between a firm (a potential applicant) and the agency. In stage zero, the players' types are determined. The agency has a three-dimensional type, $t_A = (\eta, \omega_c, \omega_m) \in \Re^3$, drawn from a common knowledge joint (normal) distribution and each firm has a two-dimensional type, $t_F = (\varepsilon, v_0) \in \Re^2$, drawn from a common knowledge bivariate (normal) distribution. The type of a player contributes to the player's valuation of a project. As will be made more precise below, both players' valuations embody idiosyncratic shocks that constitute the types. Conditional on publicly observed information the shocks are independently distributed. In stage one, the firm decides whether or not to apply to the subsidy program. The application includes a proposal for an R&D project. In stage two, the agency screens and evaluates the proposed project. It then decides the level of subsidy, s, which is the share of the investment cost covered by the agency. The subsidy level can be subject to a maximum constraint, $\bar{s}$, and the level is zero if there is no application or the application is rejected, so that $s \in [0, \bar{s}]$, $\bar{s} \leq 1$. In stage three, the firm makes the R&D investment, R, $R \in [0, \infty)$, with or without the subsidy.

Our model builds on the following assumptions:

A.1. The potential applicant is uncertain about the agency's valuation of her project.

A.2. A subsidy cannot be misused.

A.3. There are no constraints on the firm's investment.

A.4. The agency's budget constraint does not bind.

A.5. The firm's investment is non-contractible.

A.6. All potential general equilibrium effects are captured by the agency's objective function.

[5] Our model could also deal with some other treatment program than an R&D subsidy program. For example, one can think of expected employment being a project and a free or subsidized participation in an educational program being a treatment. Those who do not receive the treatment can also often participate in educational programs such as JTPA but for a full price (see e.g. Heckman and Smith, 1995), so the treatment effectively reduces the cost of educational investment. The situation we model is also close to the one in Roberts, Maddala and Enholm (1978) who study what determines whether a regulated firm requests a review of its regulated rate of return.

A.1 ensures that (in line with our data) equilibrium outcomes where a firm applies for a subsidy only to be turned down are possible. It accommodates various informational assumptions concerning the players' types. It, for example, makes no difference whether the firm's type is private information or common knowledge: it turns out that due to our functional form assumptions (see equations (1) and (5) below), the firm can neither signal its type nor does the agency care about it. For clarity, we assume that the firm's type is common knowledge.[6]

It is also immaterial whether the agency's type is private information or the potential applicant and the agency operate under symmetric but incomplete information regarding the agency's type. We only need to assume that the firm, when contemplating application, does not exactly know how the agency values her project. For brevity, we assume that the agency learns its type exactly after screening (i.e. symmetric but incomplete information regarding the agency's type prevails in the application stage).[7]

A.2 excludes moral hazard problems in the use of a treatment.[8] By A.3, the solution to the applicant's maximization problem in the last stage is interior. This assumption rules out credit rationing and ensures that a firm's project is executed even if the firm does not apply for a subsidy or the application is rejected.[9] A.4 is motivated by simplicity, but we do impose a cost of financing on the agency. A.5 is more realistic, since it prevents the firm and the agency from writing a binding contract specifying the amount the firm invests conditional on the subsidy it receives. A.6 is a weaker form of the standard, heavily criticized (e.g. Heckman, Lochner and Taber, 1998), assumption in the treatment literature that ignores general equilibrium effects. In principle the agency should be a benevolent social planner that takes into

[6] In an earlier version (HECER DP no. 76/2005) we develop a treatment program model with general functional forms. There we need to assume that the firm's type is common knowledge to rule out signalling. That is, with more general functional forms we need to make more restrictive informational assumptions.

[7] Alternatively, we could assume that the applicant has private information about the agency's returns to its project and that the agency receives a noisy signal upon it after screening the project. Since the applicant could not credibly signal its private information in our model, this assumption would yield the same optimal application and subsidy decisions as the (more realistic) assumption we use.

[8] In practice, moral hazard temptations are certainly pervasive with monetary treatments, as in our case. As a result, Tekes has several safe-guards against expropriation. For example, subsidies are only paid against receipts, there is a euro limit to a subsidy, and a significant number of subsidized R&D projects is annually randomly audited. Because the safe-guards are common knowledge, and the misuses found in the audits or otherwise are rare, we think that the assumption depicts equilibrium behavior.

[9] Although financial market failure has traditionally been a rationale for R&D subsidies, the revealed motivations for R&D subsidies have become increasingly spillover-oriented. A study using Finnish data (Hyytinen and Pajarinen 2003), and an evaluation of Finnish innovation policy (Georghiu et al. 2003) conclude that only small, R&D intensive, growth-oriented firms may face financial constraints. The situation is similar in many other industrialized countries, as the survey by Hall (2002) confirms. The decline of the financial constraint motivation for R&D subsidies is also reflected in our application: although Tekes also grants low-interest loans, most firms were not interested in them.

account all effects of the treatment. If this is the case, our model will identify general equilibrium treatment effects.

We focus on perfect Bayesian equilibria where, in stage one, a potential applicant correctly anticipates the type-contingent strategies of the agency in stage two, and where the firm's and agency's strategies are sequentially rational. In this extensive form game the firm's posterior belief concerning the agency's type after receiving a subsidy is inconsequential, so we start from the firm's maximization problem in stage three.

A Objective function of the firm and stage three of the game

We specify firm *i*'s objective function as

(1) $$\Pi(R_i, s_i, X_i, \varepsilon_i) = \pi_i + \exp(X_i\beta + \varepsilon_i)\ln R_i - (1-s_i)R_i,$$

where s_i is the subsidy (treatment), R_i is the R&D investment, X_i is a vector of observable firm characteristics, and β a vector of parameters to be estimated. The marginal profitability is also affected by a random shock, ε_i, (i.e. the (other dimension of) firm *i's* type). The random shock ε_i is distributed by nature, uncorrelated with the observable firm characteristics, observed by the firm, and unobserved by the econometrician. As explained above, it may or may not be observable to the agency. The reservation value including other projects is embodied in π_i.[10]

In stage three, the firm chooses its investment R_i to maximize (1). Since the objective function is concave in R_i, the first-order condition

(2) $$R_i = \frac{\exp(X_i\beta + \varepsilon_i)}{1-s_i}$$

gives the firm's optimal investment $R_i(s_i)$ as an increasing function of the subsidy level. Equations (1) and (2) show the economic interpretation of ε_i: a positive shock to the marginal profitability leads to a larger investment. An optimal investment given by (2) could in theory decrease profits but, in such a case, the firm would not invest at all, and consequently would not apply for a subsidy.

[10] We could also generalize (1) to multiple projects. For each firm with multiple project applications, we could treat each project as a separate observation. If the project-specific unobservables are uncorrelated, this will not materially affect estimation. The interpretation for non-applicants would be that none of their projects resulted in an application.

B Agency utility and stage two of the game

The agency's utility from applicant *i*'s project is given by

$$U(R_i(s_i), s_i, X_i, Z_i, \varepsilon_i, \eta_i) = V(Z_i, \eta_i, R_i(s_i)) + \Pi(X_i, R_i(s_i), s_i, \varepsilon_i) - gs_i R_i(s_i) - F_i, \qquad (3)$$

where F_i is the sum of the fixed costs of applying and processing the application, *g* is the constant opportunity cost of the agency's resources, e.g. the opportunity cost of tax funds. As (3) shows, the firm's utility (1) directly enters the agency's utility function.

The interpretation of *V*( ) is fundamental to our analysis. It captures the agency specific returns from the project. That is, *V*( ) captures the effects of the firm's project on the agency beyond the firm's utility and the direct costs of subsidy and the application process. In our empirical application, *V*( ) can include externalities from a firm's R&D such as consumer surplus or spillovers to other firms. At the level of an individual decision maker *V*( ) could also consist of idiosyncratic benefits from giving a subsidy such as direct (ex post) bribes or indirect ones, e.g. through a revolving door mechanism. The agency specific utility (*V*( )) can also be negative or decreasing in the investment level. For example, it is possible that some R&D projects exhibit negative externalities while being privately profitable.

In *V*( ), Z_i is a vector of observable firm characteristics, which contains the same elements as X_i. In our case, Z_i includes also the two screening outcomes (discussed next) that are observed by the agency and by the econometrician but not by the firm, i.e. that are not part of X_i. Note that *V*( ) includes also η_i, which constitutes part of the agency's type, defined as a random shock to the agency specific utility from project *i*. The shock is assumed to be distributed by nature, uncorrelated with firm characteristics, and unobserved by the econometrician. By A.1, η_i is also unobserved by the potential applicant and observed by the agency (at the latest) after application and screening takes place. In other words, A.1 means that the potential applicant is uncertain about how the agency, after screening the project proposal, sees the project and its potential to generate spillovers, consumer surplus, or private benefits to the agency's civil servants.

We assume that when deriving the optimal subsidy the agency screens - in line with reality - the application and learns, besides η_i, the two elements of Z_i that are not in X_i. The screening results in two grades on a Likert scale of 5 and we assume this to be common knowledge. The resulting 25 grade combinations are modeled by a latent regression framework. Denoting the latent value of grading dimension $j \in \{c, m\}$ for application *i* by w_{ij}^* and the observed value by w_{ij}, we get:

$$(4) \qquad \begin{aligned} & w_{ij} = h \text{ if } \mu_{h-1} < w_{ij}^* = T_i \zeta_j + \omega_{ij} \leq \mu_h \\ & h = 1,\ldots,5,\ \mu_0 \to -\infty,\ \mu_1 = 1,\ \mu_2 = 2,\ldots,\mu_5 \to \infty \\ & \omega_{ij} \sim \mathrm{N}(0,1)\ \ j \in \{c, m\},\ \mathrm{cov}(\omega_{ic}, \omega_{im}) = 0, \end{aligned}$$

where T_i is a vector of observable firm characteristics and ζ_j is parameter vector to be estimated. We assume that the unobservables ω_{ij}, which are part of the agency's type, are normally distributed and uncorrelated both with each other and other unobservables of the model. Equation (4) produces probabilities p_t^c and p_k^m of getting grades *t* and *k* in the two grading dimensions *c* and *m* (which stand for technological challenge and market risk, see the next section). In other words, p_t^c and p_k^m reflect the firm's beliefs about the agency's valuation in dimensions ω_c and ω_m .

In stage two, the agency chooses a subsidy level s_i, $s \in [0, \bar{s}]$ where $\bar{s} \leq 1$, to maximize its expected discounted utility from project *i*, taking (2) into account. To arrive at an estimable model we need to specify the effect of R_i on *V*( ). We assume that

$$(5) \qquad \partial V / \partial R_i = Z_i \delta + \eta_i,$$

where δ is a vector of parameters to be estimated. An implication of (5) is that *V*( ) is proportional to R&D investment. This may be unrealistic but similar assumptions are common in the literature on growth and R&D spillovers. We test this assumption below and do not reject it.

By using the envelope theorem, (1), (2) and (5), the first-order condition for the agency's unconstrained problem can be written as

$$(6) \qquad s_i = 1 - g + Z_i \delta + \eta_i.$$

We proceed under the assumption that (6) characterizes the maximum and verify later in the proof of the Proposition that this indeed is the case. Equation (6) shows how the agency's unconstrained decision rule is decreasing in the shadow cost of public funds, *g*. It is independent of the firm's type, ε_i, so that even if the agency did not know the private shock to the marginal profitability of R&D, it would not matter. The optimal subsidy depends positively on the shock to the agency specific utility, η_i. The minimum constraint of s=0 binds for $\eta_i \leq \underline{\eta}_i \equiv g\text{-}1\text{-}Z_i\delta$ and the maximum constraint of $\bar{s}$ for $\eta_i \geq \bar{\eta}_i \equiv \bar{s} + g\text{-}1\text{-}Z_i\delta$.

C Stage one of the game: to apply or not

In stage one, a profit maximizing firm applies for a subsidy if the expected utility from applying is at least as large as that from not applying. To calculate the benefits from applying, the firm needs to calculate the expected profits given all the possible valuations of the agency. To do this, the firm has to calculate the probabilities for a submitted application to get particular grades in the two evaluation dimensions and the expected valuation of the agency over all possible η_i. Let $\phi(\eta_i)$ define firm i's belief about the agency's type in dimension η and let $\Phi(\eta_i)$ be the corresponding cumulative distribution function. The next step is to calculate what will be the subsidy level associated with each possible valuation.

The firm weights the costs of applying against the profit increase stemming from these expected subsidies. We specify the application costs as

(7) $$K_i = \exp(Y_i\theta + v_i)$$

where Y_i is a vector of observable firm characteristics, θ is a vector of parameters to be estimated and v_i is a random cost shock (the other part of the firm's type), distributed by nature, uncorrelated with observable firm characteristics, observed by the firm, and unobserved by the econometrician and the agency (again, the latter is immaterial).

Dropping the subscript i the applicant's decision rule can be written as

(8) $$\sum_{t=1}^{5}\sum_{k=1}^{5} p_t^c\, p_k^m \{\Phi(\underline{\eta})\Pi(R(0),0) + \int_{\underline{\eta}}^{\bar{\eta}} \Pi(R(s(t,k,\eta)), s(t,k,\eta))\phi(\eta)d\eta + [1-\Phi(\bar{\eta})]\Pi(R(\bar{s}),\bar{s})\} \geq K + \Pi(R(0),0) \, .$$

The costs of applying are on the right hand side of (8). Besides the fixed costs, the firm takes into account that it can execute the project without a subsidy (A.3), in which case the project yields $\Pi(R_i(0),0)$. The expected benefits of applying are on the left hand side where the summation is over the potential screening outcomes. The first term in the curly brackets is the expected profit in case the application is rejected. The rejection occurs when $\eta_i \leq \underline{\eta}_i$, i.e. with probability $\Phi(\underline{\eta}_i \equiv g\text{-}1\text{-}Z_i\delta)$. The second term is the expected profit when $\eta_i \in (\underline{\eta}_i, \bar{\eta}_i)$ in which case the firm receives the optimal interior subsidy given by (6). The third term is the probability of receiving a maximal subsidy multiplied by the profits with the maximal subsidy. This case occurs with probability $1-\Phi\left(\overline{\eta}_i \equiv \bar{s}+g-1-Z_i\delta\right)$.

D Equilibrium of the game

We complete the model by showing that there is a unique Perfect Bayesian equilibrium. This ensures a meaningful econometric implementation of the model. Perfect Baysian equilibria in our model consist of four components: 1) A firm's decision whether to apply for a subsidy or not. Let $d_i \in \{0,1\}$ denote firm *i*'s application decision where $d_i=1$ if the firm applies for a subsidy and $d_i=0$ if the firm does not apply. 2) The firm's belief functions $p_t^c\left(d_i\right)$, $p_k^m\left(d_i\right)$ and $\phi(\eta_i, d_i)$ that describe a (common) assessment of how the agency values the firm's project given d_i. 3) The agency's subsidy decision $s_i^*(\eta_i,t_i,k_i,d_i)$ which determines the level of subsidy granted to firm *i* given d_i and the information revealed in the screening process. 4) The firm's optimal investment $R_i^*(s_i,d_i)$ given s_i and d_i.

PROPOSITION. There is a unique Perfect Bayesian equilibrium where $d_i=1$ if (8) holds, $s_i^*(\eta_i,t_i,k_i,d_i)$ is zero for $\eta_i \leq \underline{\eta}_i$, is given by (6) for $\eta_i \in (\underline{\eta}_i, \overline{\eta}_i)$ and is $\bar{s}$ for $\eta_i \geq \overline{\eta}_i$, and $R_i^*(s_i,d_i)$ is given by (2).

Proof: For brevity of notation, we drop the subscript *i* and the arguments *t*, *k*, *d*. In stage three, the firm has a well-defined best-reply function $R^*(s)$ given by (2). In stage two, the agency maximizes its expected utility conditional on its type. There is a unique type-contingent optimal subsidy if the second order condition for the agency's decision problem holds. Since we have linear constrains of minimum and maximum subsidies, it suffices to show that $U(R^*(s),s)$ is concave when evaluated at the interior solution given by (6). Differentiating (3) twice shows that $U(R^*(s),s)$ is concave if

$$\text{(9)}\quad \left(\frac{dR}{ds}\right)^2\left(\frac{\partial^2 V}{\partial R^2}+\frac{\partial^2\Pi}{\partial R^2}\right)+2\frac{dR}{ds}\left(\frac{\partial^2\Pi}{\partial R\partial s}-g\right)+\frac{d^2R}{ds^2}\left(\frac{\partial\Pi}{\partial R}+\frac{\partial V}{\partial R}-gs\right)+\frac{\partial^2\Pi}{\partial s^2}<0$$

From (1) and (4) we see that $\partial^2 V/\partial R^2$ and $\partial^2\Pi/\partial s^2$ are zero. Together with the envelope theorem ($\partial\Pi/\partial R=0$) they imply that (9) can be simplified to $\left(\frac{dR}{ds}\right)^2\frac{\partial^2\Pi}{\partial R^2}+2\frac{dR}{ds}\left(\frac{\partial^2\Pi}{\partial R\partial s}-g\right)+\frac{d^2R}{ds^2}\left(\frac{\partial V}{\partial R}-gs\right)<0$. Using (2) and (5) we get $-\left(\frac{R}{1-s}\right)^2\left(\frac{\exp(X\beta+\varepsilon)}{R^2}\right)+\frac{2R}{1-s}(1-g)+\frac{2R}{(1-s)^2}(Z\delta+\eta-gs)<0$, which using (2) further simplifies to $\frac{R}{1-s}\left[-1+2(1-g)+\frac{2(Z\delta+\eta-gs)}{1-s}\right]<0$. Evaluating this expression at the interior solution given by (6) yields s-1<0. Consequently, there is a unique maximum that solves the agency's decision problem. Because the optimal unconstrained subsidy (6) is increasing in η, $s^*(\eta)=0$ for $\eta\leq\underline{\eta}$, $s^*(\eta)$ is given by (6) for $\eta\in(\underline{\eta},\overline{\eta})$ and $s^*(\eta)=\bar{s}$ for $\eta\geq\overline{\eta}$. Thus, the optimal type-contingent action of the agency in stage two is unique. In stage one the firm decides whether to apply or not given $s^*(\eta)$ and p_t^c, p_k^m and $\phi(\eta)$. Since in a Perfect Bayesian Equilibrium the firm's belief must be consistent with the agency's strategy, d_i=1 if (8) holds. Clearly, the agency's best response to *d=1* is $s^*(\eta)$ so we have found a Perfect Bayesian equilibrium. Since the utility maximizing action in each stage of the game is unique, the equilibrium is also unique. ■

III Finnish innovation policy, Tekes and data[11]

A Innovation policy and Tekes

In 2001 Finland invested 3.6 per cent of GDP – 5 billion euros - on R&D. Tekes is the principal public financier of private R&D in Finland.[12] The primary objective of Tekes is to promote the competitiveness of Finnish industry and the service sector by providing funding and advice to both business and public R&D. To achieve these goals, Tekes strives to increase Finnish firms' R&D and risk-taking. Tekes is also responsible for allocating funding from European Regional Development Funds (ERDF). Funding from ERDF is subject to the general funding criteria of Tekes, but it is meant for least-favored regions. As a result, Tekes funding has also a regional dimension through ERDF. Finnish regions differ greatly in their socio-economic characters, economic performance, and their R&D-intensity, e.g. some 20% of the population lives in the capital region in Southern Finland where also a large part of the economic activity and most of R&D takes place.

[11] As our application data is from Jan. 2000- June 2002, we use 2001 figures to describe the environment. One of us spent nine months in Tekes to get acquainted with the actual decision making process. Among other things she participated in the decision making meetings. Public information about Tekes can be found at http://www.tekes.fi/eng/, accessed December 20th, 2004.

[12] Main public funding organizations in the Finnish innovation system in addition to Tekes are the Academy of Finland, Employment and Economic Development Centers (T&E Centers), Finnvera, Industry Investment and Sitra. Also the Foundation of Finnish Inventions (Innofin) provides financial support for innovation. See Georghiu et al. (2003) for a recent description and evaluation of the Finnish innovation policy institutions.

Besides funding business R&D, Tekes finances feasibility studies, and R&D by public sector including scientific research. In 2001 Tekes funding amounted to 387 million euros, and it received 2948 applications of which almost exactly 2/3 were accepted. The number of applications by the business sector for R&D funding was 1357 and, again, 2/3 of them were accepted. In monetary terms, the business sector applied for 526 million euros while 211 million euros were granted to it.

Business R&D funding consists of grants, low-interest loans and capital loans. Tekes' low-interest loans not only have an interest rate below the market rate but they are also soft: If the project turns out to be a commercial failure, the loan may not have to be paid back. A capital loan granted by Tekes differs from the standard private sector debt contract in various ways: it is included in fixed assets in the balance sheet, it can be paid off only when unrestricted shareholders' equity is positive and the debtor cannot give collateral for the loan. The share of each instrument of the total funding allocated to business R&D in 2001 was 69 %, 18% and 13 %. Subsidy applications covered 83 % of the amount applied whereas in terms of granted amount subsidies' share was 67%. The overlook of loans by applicants suggests that they do not encounter significant financial constrains, supporting our assumption A.4 (cf. footnote 9).

The application process from the submission to the final decision, which to our understanding is well known among potential applicants, proceeds along the lines of the theory model of Section II. There are two things worth mentioning: First, an application has to include the purpose and the budget of the R&D project for which Tekes funding is needed, and the applied amount of funding in euros. We utilize this below. Second, Tekes screens the application and grades it in several dimensions using a 6-point Likert scale from 0-5, not two, as we assume for simplicity. However, according to Tekes' civil servants, the most important dimensions in project evaluation concern the technological challenge of the project and its market risk which are the dimensions we include.[13] Tekes' public decision criteria are: The project's effect on the competitiveness of the applicant, the technology to be developed, the resources reserved for the project, the collaboration with other firms within the project, societal benefits, and the effect of Tekes' funding. Tekes takes into

[13] A loose translation of grades of technological challenge is 0 = 'no technical challenge', 1 = 'technological novelty only for the applicant', 2 =' technological novelty for the network or the region', 3 = 'national state-of-the-art', 4 = 'demanding international level', and 5 = ' international state-of-the-art'. For market risk, it is 0 = 'no identifiable risk', 1 = 'small risk', 2 = 'considerable risk', 3 = 'big risk', 4 = 'very big risk', and 5 = 'unbearable risk'.

account whether the application comes from an SME and, as mentioned above, it also has a regional dimension through ERDF.

Tekes’ final decision is based on the proposed budget of the project before the R&D investments are made, but the actual funding is only given ex post against the incurred costs. Decision making is constrained by the rules preventing negative subsidies and very large subsidies both in relative and absolute terms. In other words, a subsidy is granted ex ante as a share of to-be-incurred R&D costs. There is an upper bound for this share: If the firm fulfils the EU SME criterion, the upper bound is 0.6, otherwise 0.5.[14] The actual funding then covers the promised share of incurred costs up to a specified euro limit. The limit should allow the promised reimbursement of investment costs up to the profit maximizing level but prevent Tekes from covering costs extraneous to the project proposal.[15] In terms of our model, these practices amount to $\underline{s}=0$, $\bar{s}\in\{0.5,0.6\}$ and a goal of setting the euro limit at $sR(s)$.

Tekes also sometimes adjusts a proposed budget, both down and up, when an applicant, e.g. applies subsidies for costs that Tekes cannot cover. In practice an upward adjustment is rare and in principle occurs only if a project significantly changes character during the application process. Such upgrades can thus be taken as exogenous events that cannot be manipulated by Tekes to overcome the institutional limits on its subsidy allocation.

B Data

Our data come from two sources. The project level data come from Tekes, containing all applications to Tekes from January 1st 2000 to June 30th 2002. They consist of detailed information on the project proposals and Tekes' decisions. The firm level data covering originally 14 657 Finnish firms come from Asiakastieto Ltd, which is a for-profit company collecting, standardizing, and selling firm specific quantitative

[14] Given our data, it is unlikely that firms deliberately keep themselves below the EU SME boundary requiring that a firm has less than 250 employees and has either sales less than 40 million euros or the balance sheet less than 27 million euros. Most of the firms in our data are well below the boundary, as 95% them have less than 110 employees, less than 14 million euros in sales, and a balance sheet of less than 11 million. As the SME criterion also maintains that large firms can hold at most 25% of a SME’s equity and votes, it is unlikely that many of the SMEs are subsidiaries of large firms. We thus consider the SME status of a firm exogenous.

[15] As mentioned in footnote 8, the euro limit alleviates the moral hazard problem. There are also other reasons for the limit. Because Tekes has an annual operating budget, a practical decision rule is to cap the euro amount using the proposed budget, as it is the best available information at the time the subsidy decision is made. Tekes is also monitored both by the press and politicians. Tekes civil servants may want avoid the accusations of granting larger subsidies than originally planned. At the same time, however, there may be a desire to make the limit high enough to allow profit maximizing behavior of applicants.

information.[16] Asiakastieto's data are based on public registers and on information collected by Asiakastieto itself. The data contain for example, firms' official profit sheet and balance sheet statements, and include all the firms who file their data in the public register or submit the information to Asiakastieto. We use the 1999 cross section, i.e. all firm characteristics are recorded earlier than the application data. The sample was drawn from Asiakastieto's registers in 2002 according to three criteria: i) the most recent financial statement of the firm in the register is either from 2000 or 2001; ii) the firm is a corporation; and iii) the industrial classification of the firm is manufacturing, ICT, research and development, architectural and engineering and related technical consultancy, or technical testing and analysis. Firms in these industries are most likely to apply for funding from Tekes. After cleaning the data of firms with missing values, we are left with 10 944 firms. These firms form a large proportion of the population of potential applicants, and they constitute our sample of potential applicants.

Some 1000 firms from outside our sample filed applications to Tekes during the observation period. There are three principal reasons for the exclusion of an applicant from our sample: 1) the firm did not exist in 1999; 2) the firm did not operate in the industries from which the sample was formed; and 3) the firm was so small that it was not obliged by law to send its balance and profit sheets to the official registry.

The data we use in the estimations comprises 915 applications, where we have limited the count to one per firm by using the first application by each firm within our observation period.[17] 722 of these applications were accepted, i.e. received a positive subsidy share. Table 1 displays summary statistics of our explanatory variables for potential applicants, and Table 2 conditions the statistics on the application decision and success. As Table 1 shows, potential applicants are heterogenous. They are on average 12 years old with 35 employees. A very high proportion are SMEs according to the official EU standard (cf. footnote 14). As explained, the SME criterion determines the upper bound of the share of the R&D costs covered by Tekes, and we therefore need to take it into account in our

[16] More information about Asiakastieto can be found at http://www.asiakastieto.fi/en/, accessed June 20th, 2005.
[17] Several firms in our data had multiple applications during our observation period. The firms in our sample account for roughly half of all applications.

estimations. Sales per employee, a measure of value added, is 165 000 euros. Some 6% are exporters. [18]

[TABLE 1 HERE]

We also have information on two corporate governance variables. In some 14% of potential applicants, the CEO is also the chairman of the board. Such an arrangement can, on the one hand, improve the information flow between the board and the executive but, on the other hand, weakens the board's independence. The board of an average potential applicant has four to five members. A larger board is costlier but is more likely to include members with outside knowledge that may be useful either in conducting R&D (e.g. choosing among competing projects, organizing management of current projects, monitoring), or in the application process itself.

From Table 2 we see that applicants are larger than non-applicants and successful applicants larger than rejected ones. The median number of employees for non-applicants is 5, for applicants 26, and for rejected applicants 21. The applicants also tend to have larger boards. Quite naturally, applicants have more previous applications on average than non-applicants. The difference in both means and medians is 4.

Table 3 reports information about applications and Tekes' decisions. Some 21% of applications are rejected. The proposed projects involve on average an investment of 630 000 euros; the rejected proposals are clearly smaller with a mean of 385 000 euros. According to Tekes' rating, the projects have on average a technical challenge of 2 (scale 0-5), and rejected proposals have on average a lower score of 1.5. The mean risk score is also 2, and it is the same for successful and rejected applications (see the Appendix for more information).

[TABLE 2 HERE]

As explained, Tekes grants low-interest and capital loans besides subsidies. Because it is hard to calculate the value of such non-standard loans to the applicants, we pool the instruments. We thus define the subsidy per cent as the sum of all three forms of financing, divided by accepted proposed investment. As some 60% of

[18] The figure excludes firms with both exports and imports. We have repeated our estimations by including in the "exporter" category all firms that report exports regardless of whether they report imports or not. The results are qualitatively identical, and quantitatively close to those reported.

applicants only apply for a subsidy, and over 80% are only granted a subsidy, this seems a reasonable simplification. Measuring a subsidy in this way, 0.4% of applicants get the maximum subsidy.[19] Successful applicants receive on average a subsidy that covers 32% of the R&D investment costs. We test the robustness of our results to the definition of a subsidy by using only pure subsidies as the dependent variable in the Tekes decision rule.

[TABLE 3 HERE]

IV The econometric model

A The model

We now operationalize the model presented in Section II. Using (1), (2) and (7), and taking logarithms on both sides, the application rule can be derived from (8) (again, subscript *i* omitted) as

(10) $$d = 1\left[X\beta - Y\theta + \ln \sum_{t=1}^{5} \sum_{k=1}^{5} p_t^c p_k^m \left\{ \int_{\underline{\eta}}^{\overline{\eta}} -\ln\left(1 - s(t,k,\eta)\right)\phi(\eta)d\eta - \left(1 - \Phi(\overline{\eta})\right)\ln(1-\bar{s}) \right\}\right] \geq \nu - \varepsilon$$ [20]

In words, the application rule is given by an indicator function d_i that takes the value one if firm *i* finds it profitable to apply for a subsidy. The investment equation can then be rewritten, upon taking logarithms of (2), as

(11) $$\ln R_i^*(s_i) = X_i\beta - \ln(1-s_i) + \varepsilon_i,$$

with observation $\ln R_i = d_i \ln R_i^*$ and the agency decision rule (6) as

(12) $$s_i^* = (1-g) + Z_i\delta + \eta_i,$$

[19] There is a cluster of firms right below the maximum subsidy: 1.9% of applicants get a subsidy which is less than one percentage point below the maximum subsidy, and 2.5% get a subsidy less than 5 percentage points below the maximum. At the lower end there is no such clustering: on the contrary, no firm gets a subsidy that is less than 2.9%: however, 2.6% of applicants get a subsidy that is greater than 2.9% and less than 5% .

[20] Note that we can take logarithms on the inequality since the term $\sum_{t=1}^{5}\sum_{k=1}^{5} p_t^c p_k^m \left\{ \int_{\underline{\eta}}^{\overline{\eta}} -\ln\left(1 - s(t,k,\eta)\right)\phi(\eta)d\eta - \left(1 - \Phi(\overline{\eta})\right)\ln(1-\bar{s}) \right\}$ is always greater than zero.

with observations $d_i s_i = 0$ if $s_i^* \le 0$ and $d_i s_i = \bar{s}$ if $s_i^* \ge \bar{s}$. Our econometric model can thus be summarized by *the screening equations (4), the application equation (10), the investment equation* (11) and *the Tekes decision rule* (12).

B Statistical assumptions, identification and estimation

We now explain our statistical assumptions, how identification takes place, and how we estimate the model. Our econometric model contains five unobservables, ω_j, *ε*, *η* and *ν*. They are assumed to be uncorrelated with the observed applicant characteristics. Estimating the model without imposing restrictions on the covariation of the unobservables is in principle possible by using a simulation estimator. However, assuming that η is uncorrelated with *ε* and ν_0 yields a large reduction in computational cost, because then the Tekes decision rule (12) is no longer subject to a selection problem. This means that estimation can be broken into three steps. Since our tests (see below) indicate that we cannot reject the Null hypothesis of no correlation between $\varepsilon - \nu$ and η, in estimating the model by (pseudo-) ML, we impose

A.7 a) $\nu = (1+\rho)\varepsilon + \nu_0$, b) $\eta \perp \varepsilon$, c) $\eta \perp \nu_0$, d) $\varepsilon \perp \nu_0$, e) $\omega_j \perp \varepsilon$, f) $\omega_j \perp \eta$, g) $\omega_j \perp \nu_0$, h) $\eta \sim$ N(0, σ_η^2), i) $\varepsilon \sim$ N(0, σ_ε^2), j) $\nu_0 \sim$ N(0, $\sigma_{\nu_0}^2$).

In words, the unobservable (*η*) affecting the agency specific utility is uncorrelated both with the unobservable (*ε*) affecting the marginal profitability of the applicant's investment and with the unobservable (*ν*) affecting the application cost. The screening equation unobservables (ω_j) are uncorrelated with all other shocks. As A.7a) shows, there is no restriction on the correlation between *ν* and *ε*. A.7h)-j) may be relaxed when we use semi-parametric estimation methods.

The first step is the estimation of the ordered probit the screening equations (4). By using the estimates we can calculate the firms' expected probability that a submitted application gets a particular grade in the two evaluation dimensions. Our assumption that the unobservables are normally distributed allows us to identify the coefficients up to scale.

The second step is to estimate the Tekes decision rule (12). In estimation we use the actual values for the grades from the evaluation of each project. The Tekes decision rule identifies *δ*, i.e. the effect of observed applicant and project characteristics on the agency specific utility derived from the project. If we impose A.7b) and A.7c), we can estimate (12) using a double-hurdle Tobit model without correcting for selection. To test whether A.7b) and c) hold, we estimate a sample selection double-hurdle Tobit and test for the significance of the Mills ratio term. We also use an alternative, more flexible, approach of nonparametrically estimating (12) by a two-limit version of Powell's (1984) CLAD estimator.

After estimating the agency's screening equation and its decision rule, we calculate the effect of subsidies on the applicant's expected profits, replacing the unobservable parts in the application equation (10) with their estimated counterparts. In step three we then estimate the application and investment equations (10) and (11) by using both ML and a semi-parametric variant of the approach suggested by Das, Newey, and Vella (2003, henceforth DNV).[21]

Our data contains information on the proposed R&D investments, not the realized one. However, we can identify the parameters of the investment equation (11) by estimating a slightly modified version of the equation. The model implies that an applicant strictly prefers proposing a budget based on a maximum subsidy per cent over proposing any smaller amount, and is indifferent between proposing that budget and any larger amount.[22] Consequently, we will estimate (11) using data on proposed R&D budgets by inserting $\bar{s}$ into (11). As explained in section III.A Tekes sometimes adjusts a proposed budget, e.g. when an applicant applies for subsidies for costs that Tekes cannot cover. To take into account such applicants' mistakes that may inflate the proposed R&D investments, we use the measure 'accepted proposed investment' as our dependent variable in the R&D equation. We test the robustness of our results by using the R&D investment proposed by the applicant as an alternative dependent variable.

The application equation (10) allows us to identify how observed applicant characteristics affect the fixed costs of application without having to resort to an exclusion restriction. Our theoretical model suggests a form for the error term in the application equation and, as a result, we identify the correlation between ν_i and ε_i when using ML. Moreover, we can identify the variance of the error term in the application equation since following theory the coefficient of the summand

[21] Manski (1989) compares merits of the parametric and non-parametric approaches. Manski argues that, although the nonparametric approach appears to be more flexible, it involves arbitrary exclusion restrictions. Therefore it is not necessarily preferable over the parametric one.

[22] Too see this, recall first that the applicant does not know Tekes' type (A.1) and the subsidy share is bounded above at $\bar{s}$. As mentioned in Section III.A, there is also an euro limit to the ex post reimbursements which is based on the proposed budget. Then, since $\partial\Pi/\partial s>0$ by (1), the applicant wants as high a subsidy as possible. Therefore it proposes an optimal project based on the maximum subsidy share, $R^*(\bar{s})$. Proposing anything less risks foregoing profits in case where the actual subsidy turns out to be larger and the applicant subsequently reoptimizes because of the euro limit. On the other hand, the applicant would never want to implement a project larger than $R^*(\bar{s})$, and it is indifferent between announcing $R^*(\bar{s})$ and any larger budget, given the assumption that it cannot misappropriate the funds.

$$\ln \sum_{t=1}^{5} \sum_{k=1}^{5} p_t^c p_k^m \left\{ \int_{\underline{\eta}}^{\overline{\eta}} -\ln(1-s(t,k,\eta))\phi(\eta)d\eta - (1-\Phi(\overline{\eta}))\ln(1-\overline{s}) \right\}$$ is constrained to unity.[23]

Our model implies that the applicant's best-reply function, $R_i(s_i)$, is increasing in treatment and is heterogenous both with respect to observables and the unobservable profitability shock. Correcting for selection bias by using the application equation (10), we obtain consistent estimates of β that determine the effect of the observable applicant characteristics on the marginal profitability of the R&D-investment. To obtain consistent standard errors in the application and investment equations, we bootstrap the whole model (4), (10)-(12) when using both ML and the semi-parametric estimator.

Note also what we cannot identify. In (1) we are unable to identify π_i, the applicant's reservation value, from the constant in X_i. Our cross section estimates are however not affected by unobserved differences in the reservation value. Similarly, in (12) we cannot identify separately *g*, the opportunity cost of government funds, and the constant in δ. Nor can we identify *V*( ), since (12) cannot be integrated to a unique number. Given (5), however, a constant in *V*( ) would imply that a project generates agency specific returns even when the R&D investment is zero. As this is an unappealing scenario, we feel justified in assuming that there is no constant in *V*( ). We are also unable to identify the agency's screening costs (F_i-K_i). This will result in an upward bias in the welfare calculations if these costs are significant. Finally, in the semi-parametric estimation of the application and investment equations, the parameters of the application cost function cannot be identified.

V Estimation results

We include the following firm characteristics into all estimation equations: age, the log of the number of employees, sales per employee, an SME dummy, a dummy for a parent company, the number of previous applications, a dummy indicating if the CEO acts as the chairman of the board, board size, and a dummy for exporters. We also

[23] This implication of our theoretical model cannot be tested. If we imposed the standard variance normalization, the coefficient of the term would be $1/\sigma_{\varepsilon-\nu}$ instead of unity.

include industry and region dummies.[24] In the reported specifications, we use a slightly different set of explanatory variables in the screening equations and the Tekes decision rule on the one hand, and the application and investment equations on the other. For example, we include the squares of the continuous variables only when reporting the estimations of the investment and application equations.[25] The results from the screening equations are reported in the Appendix. We also have estimated the model (by ML) excluding the observations in the 99th size (sales) percentile, with essentially identical results to those reported. Other robustness checks will be taken up in the context of the appropriate estimation.

A The Tekes decision rule and agency specific returns

In Table 4 we report the estimation results concerning Tekes' decision rule. Recall that the coefficients can be interpreted as the marginal effects of R&D on agency specific benefits. By using ML (column one) we find that the more challenging a project is technically, the higher is its subsidy rate. A one point increase on the 5-point Likert scale leads to a 10 percentage point increase in the subsidy rate. Market risk carries a negative but insignificant (p-value 0.13) coefficient. Firm size obtains a positive and significant (at 10% level) coefficient. A possible interpretation is that in Tekes' view, moving an otherwise identical R&D project into a larger firm creates larger positive externalities, e.g. through higher employee rents. As against Tekes' stated preference that allows a 10 percentage points higher level of maximum subsidy for SMEs, it is unsurprising that SMEs are granted a higher subsidy, everything else equal: The difference is 8.5 percentage points. The corporate governance variables and the number of previous applications have no effect.

We relegate the details of the coefficients of industry dummies to the Appendix. The only industry dummies with significant coefficients are food (p-value .000) and data processing (p-value .081). Using metal manufacturing firms as a reference group, firms in the food industry received a substantially higher subsidy, of the order of 25 percentage points, whereas data processing firms obtained subsidies that were 6.5 percentage points lower. During our observation period, Tekes was actively seeking applications from the food industry, which at least partially explains the findings concerning the industry.

[24] We divide Finland into five regions: Southern, Western, Eastern, Northern and Central Finland. Of these, Eastern and Northern Finland are the least developed. We did try interactions between firm characteristics and industry and region dummies.

[25] To speed up the computation of the bootstrap we used LR-tests to narrow the set of explanatory variables in each equation. The second order terms were excluded from the screening equations and the Tekes decision rule based on the LR-tests.

Another finding left to the Appendix is that regional aspects seem to influence Tekes' decision making: Firms in Eastern and Central Finland obtain subsidies that are 7-10 percentage points higher than they would obtain if they were in Southern Finland. That regional policy matters is, however, debatable, as the city of Oulu, which is located in Central Finland is one of the R&D centers in Finland. Moreover, we find that firms in the depressed and sparsely populated Northern Finland do not get higher subsidies. This finding is perhaps not robust as only 2% of our sample firms come from Northern Finland.

[TABLE 4 HERE]

The above results are obtained under the assumptions A.7b) and A.7c), which maintain that the error in the Tekes decision rule uncorrelated with the errors in the investment and application equations. To test these assumptions, we estimated a two stage selection model. We first estimated a probit application equation[26] and then re-estimated the Tekes decision rule by inserting the Mills ratio into it. The Mills ratio obtained small negative (less than 0.2 in absolute value) and imprecisely estimated coefficients in all of the several specifications that we tried. This suggests that our assumptions A.7b) and A.7c) of no correlation are reasonable. The economic significance of the no-correlation finding is tied to the interpretation of *V*( ). As we will elaborate in sections VI.B and VI.C, if one is willing to assume that *V*( ) captures social surplus, it will most likely consist of domestic spillovers between firms in Finland. With this interpretation, the finding implies that project specific spillover shocks are unrelated to project specific profitability shocks.

We also tested our assumption that *V*( ), the agency specific utility, is linear in applicant investment as implied by (5). Were *V*( ) non-linear in the applicant's investment, the Tekes decision rule would contain an investment term (*R*) or its interactions with observable applicant characteristics. After incorporating such terms into the Tekes decision rule, we could not reject the Null of (joint) insignificance of the terms. Again, the economic implications are tied to the interpretation of *V*( ). The result suggests that the agency specific benefits from a project are linear in R&D.

[26] Naturally, the probit was run without the expected subsidy term, but with and without added interactions to improve identification.

We also estimated the Tekes decision rule by a two-limit version of Powell's (1984) CLAD estimator.[27] This allows for nonparametric estimation of (two-limit) censored regressions. As column two of Table 4 shows, the results are relatively close to those obtained using Tobit ML. The only noteworthy differences are that with CLAD, the rubber industry obtains a significant positive coefficient (approximately 0.008 in value, compared with 0.012 for Tobit), and the coefficient of Central Finland is no more significant. There are some relatively large differences between the insignificant coefficients, though.

Finally, to test whether measuring the subsidy per cent by summing subsidies, low-interest loans and capital loans affect the results, we estimated the two-limit Tobit using only subsidies, excluding the loans. Column three reveals that our results are not driven by our definition of the dependent variable.[28]

B Cost of application function

In Table 5 we report the estimates of the application cost function (equation (7)).[29] Age, SME status, CEO being chairman, and parent company status have no statistically significant effect, but firm size has a non-linear decreasing effect on application costs. Sales per employee increase application costs. One interpretation is that firms producing high value added products have complicated R&D projects based on soft information that are laborious to write down. Another is that because the opportunity costs of the effort of making and promoting an application are probably far greater than the direct monetary costs of filling in and filing it, firms with high value current production have higher opportunity costs of applying. The size of the board has a decreasing effect on application costs. This may reflect the role of external knowledge in lowering application costs. Exporters have lower costs, maybe because they are relatively more experienced in dealing with government bureaucracy than non-exporting firms.

[TABLE 5 HERE]

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[27] The two-limit CLAD was estimated by using the following algorithm: we first estimated a LAD using all 379 observations, then excluded all observations with predicted values less than the minimum or more than the maximum allowed, and re-estimated the LAD. This was repeated until convergence.

[28] We also checked whether the definition of the dependent variable in the Tekes decision rule affects our parameter estimates in the sample selection model (application and R&D investment). The R&D investment equations' parameters are virtually identical, as are most of the parameters of the application equation. All parameters in the application equation are within one standard deviation of each other.

[29] We only present results from the model where the log of accepted proposed investment was the dependent variable in the 2nd stage investment equation as results using the log of proposed investment yielded essentially identical results.

The number of past applications has a nonlinear effect, first decreasing and then, after 141 applications, increasing application costs. Increasing the number of past applications from non-applicants' median of zero to applicants' median of two decreases application costs by 35%. One prior application decreases costs by 20% and four by 58%. It seems that learning by doing is going on. Given that our data is cross sectional, however, it is possible that instead of being attributed to path-dependence, the results are generated by unobserved heterogeneity.

C Investment equation

Recall that our investment equation (10) identifies the effects of exogenous variables on marginal profitability of R&D investment. In view of the received R&D literature, it is likely that unobserved heterogeneity accounts for a substantial part of the marginal profitability of R&D. This is also what we find, as Table 6 shows. Firms with higher value-added current production have higher marginal profitability of R&D whereas it appears to be lower in firms with CEOs as chairmen. Other findings are not robust over specifications. In column one where we report the results from the specification with the quadratic terms the number of previous applications and being an exporter also carry significant coefficients.[30] In the specification without the quadratic terms, we find that larger firms, measured by the log of the number of employees, have higher marginal profitability of R&D. Henderson and Cockburn (1996), the only other study known to us that employs project level data, report a similar result.

To test the robustness of our results, we estimated the model using DNV's semi-parametric sample selection estimator. We imposed otherwise the structure of the ML specification, but allowed the additively separable error terms to have an unknown distributions. The results, presented in column three of Table 6, are in line with the ML estimates: Most coefficients are within the ML 95% confidence intervals. This suggests that our ML distributional assumptions are not biasing the parameter estimates. The propensity score carries a negative coefficient as expected (significant at 12.5% level). Following DNV we interpret that there is evidence in favor of normal disturbances, because cross-validation (CV) suggests that no higher order terms of the propensity score are needed.[31]

[30] Several industry and region dummies carried significant coefficients, too.

[31] We used the same trimming and transformation DNV. The transformation gives exact sample selection correction for Gaussian disturbances. The trimming explains the difference in the sample size compared to ML estimations. We tried up to the 4th order terms for the variable capturing the effect of subsidies on

[TABLES 6 AND 7 HERE]

Finally, we estimated the investment equation using the R&D investment proposed by the applicant as an alternative dependent variable. The results, presented in column four, are close to those in column one.[32] The one notable difference is that the coefficient of the CEO as chairman variable, although close in value, is no longer statistically significant. It thus seems that the definition of the dependent variable is not driving the results.

D Covariance structure

As Table 7 shows, we are able to identify the variances of all error terms, and the covariance between the unobservables in the application and investment equations. The coefficient determining the variance share of the unobservable of the investment equation in the unobservable of the application cost function (equation (7)) obtains a value of 1.5. Ceteris paribus, the higher the unobserved marginal profitability of the R&D project of a firm, the less likely it is that the firm will submit an application. Similar to the finding that sales per employee increase application costs, it could be that projects with higher marginal profitability of R&D are more complicated involving tacit knowledge and are therefore more difficult to describe in an application. Moreover, the application costs are essentially opportunity costs, which should be higher for projects with higher marginal profitability of R&D.

VI Implications of the results

The structure of our model can be utilized to back out a number of figures that provide insights into the efficiency of R&D investment and subsidies. In addition the estimated model can be used to analyze the effects of application costs. We first report implications about expected benefits and rates of return to R&D, then discuss

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expected discounted profits in the 1st stage, and started from the ML specification. CV indicated that we should include the subsidy-terms up to the 3rd order, but should not include interactions of the other explanatory variables. In the 2nd stage, we kept the same specification as in ML, and experimented with including up to the 4th order transformation of the propensity score (without interactions with explanatory variables). Only the 1st order propensity score variable obtained a significant coefficient, and CV confirmed that we only should use the 1st order propensity score. CV-values are reported in the Appendix. We used a Gram-Schmidt ortho-normalization for the 3rd and 4th order terms in both stages.

[32] The results using the restricted specification are close to those reported in column two.

our findings on treatment effects and finally present implications about the application costs. We conclude by characterizing the distribution of R&D benefits.

In calculating the figures, a key idea is to exploit the information on unobservables that the covariance structure and the application equation yield. Since the indicator function in (10) takes value one for applicants and zero for non-applicants, we can condition the expected values of the unobservables on the value of the indicator function. We base the calculations on results derived using the accepted proposed investment as the dependent variables and report medians. All our figures refer to expectations formed prior to the launch of a project. Consequently, when we talk about profits, utility, welfare or rate of return, we always mean expected discounted ones. For brevity, we drop the 'expected discounted' from the text. In order to analyze the differences between the group of non-applicants and the group of applicants, we report all the figures for both groups.

A Profitability and the rate of return to R&D

Profitability of R&D and the rate of return to R&D indicate the efficiency or productivity of R&D investments. According to our model, profits on the non-applicants' projects are 13 million euros whereas they are only 2.7 million euros on the applicants' projects. In addition we find that in the absence of subsidies, the applicants' projects generate an agency specific median utility of 68 000 euros, the corresponding utility from non-applicants' projects being 319 000 euros. Applicants' projects are thus privately and socially less valuable than those of non-applicants. However, the ratio of agency specific to private median benefits is somewhat higher for applicants than non-applicants.

The estimated private returns to R&D investment are very high for applicants (median close to 1000%), and even higher for non-applicants. Joint returns to R&D investment are appreciably higher, but the differences are dominated by the very high private returns. The private returns may seem too high for comfort even keeping in mind that these figures are based on firms' plans rather than on realizations, but most of the prior literature's results also indicate very high returns. For example, Griliches (1964) estimates a social return of 13$ on a dollar of R&D in agriculture, Mansfield et al. (1977) report an average social rate of return of over 80% and Griliches (1998, pp. 67) reports private rates of return in the interval [.03, 1.03]. More recently, Udry and Anagol (2006) report returns of 300% for pineapple cultivation in Ghana and explain it by appealing to unobserved returns to innovation and experimentation related to this relatively new (in Ghana) crop.

The relative dominance of private returns is understandable, because Tekes and the firms operate in a small open economy from which most of the consumer surplus and spillovers flow abroad.[33] If Tekes is maximizing domestic welfare, it should ignore those effects, implying that private returns constitute a large part of joint returns. The distribution of private and, hence, joint returns to R&D, is skewed (see Figure 1 for non-applicants' private returns w/o subsidies), confirming earlier results (Pakes 1986, Scherer and Harhoff 2000).

[FIGURE 1, TABLE 8 HERE]

B Treatment effects

The literature on treatment effects emphasizes the effects of the treatment on the treated. In our case this treatment effect is the effect of the subsidy on the profits of subsidized applicants, i.e the change in profits due to subsidy. We call this the private treatment effect. It is heterogenous across firms as it depends on both observable and unobservable applicant characteristics. In addition to this standard treatment effect, our approach allows the identification of several other relevant treatment effects.

First, our model suggests that a subsidy has an effect on the agency beyond that on the applicant. We name the subsidy-induced change in the agency specific utility the subsidy the agency treatment effect.[34] If one assumes that the agency is a benevolent social planner, $V(\ )$ will capture all general equilibrium effects of a treatment outside those appropriated by the applicant. Consequently the joint effect of the treatment on the agency and the subsidized applicant will constitute the social treatment effect, i.e., increase in joint welfare due to the subsidy.

Second, the inclusion of application costs in the analysis makes it possible to differentiate between gross and net effects of the treatment. Usually only gross treatment effects, i.e. those that do not take into account application costs, are analyzed. Third, in addition to the actual treatment effect[35] (treatment on the treated), we can calculate the expected treatment effect on the applicants and the non-

[33] The literature on R&D, geography and trade (see e.g. Eaton and Kortum 2002) finds that much of the spillovers are international.
[34] The calculations are based on the assumption that the shadow cost of taxes, g, is 1.2. Kuismanen (2000) estimates the dead-weight loss of existing Finnish taxation to be 15% using labor supply models. Both the constant of integration and the fixed costs of screening applications (i.e. $F_i=K_i$) are ignored.
[35] In other words, actual means that the treatment is realized. Naturally, these are still expected discounted effects.

applicants. In other words, our model makes it possible to touch upon the issue of what would have been the effect of the treatment on the non-applicants.

In reporting the figures, we thus divide the treatment effects into private (firm), agency, and joint treatment effects. Joint refers to the sum of private and agency treatment effects. Note that all these treatment effects are expected, not realized, ones as our calculations reflect the expected effect of the treatment prior the launch of the project. The difference between treatment effect and expected treatment effect in the text is that the former is calculated based on the actual, the latter using the anticipated, subsidy.

We first report the net treatment effects based on actual treatments on the subsidized applicants. In the text below, we always refer to net figures unless otherwise stated. The median increase in the subsidized applicants' profits due to subsidies is 30 000 euros whereas the median agency treatment effect is 44 000 euros. Together these generate the median joint treatment effect (welfare increase) of 74 000 euros. The median increase in the subsidized applicants' profits ignoring the application costs is 65 000 euros. Thus, ignoring application costs severely biases the estimated effects upwards.

The median joint rate of return on the subsidy is 0.80; ignoring application costs the corresponding figure is 1.22.[36] The joint rate of return on the subsidy program is 0.74, taking into account also the application costs of the applicants that did not receive a subsidy.[37] Ignoring application costs yields a joint rate of return on the subsidy program of 1.22. Note that the rates of return taking into account application costs are smaller than the estimate we use for the shadow cost of public funds (g=1.2), meaning that costs overweigh the benefits. We next compare the expected treatment effects for the non-applicants and the applicants using expected subsidies.

The median increase in the applicants' and non-applicants' profits due to expected subsidies are 11 000 euros and -1.9 million euros respectively. The corresponding figures for gross profits are 46 000 euros vs. 206 000 euros. This highlights how the high application costs make it unprofitable for the non-applicants to apply. To make the comparisons between non-applicants and applicants more meaningful, we ignore the applications costs below. As indicated above, the median

[36] The joint rate of return is defined as the sum of agency specific utility and firm profits net of application cost divided by subsidy amount in euros, where the subsidy amount in euros equals subsidy times the expected R&D investment, conditional on the subsidy.

[37] The joint rate of return on the subsidy program is the overall benefits due to subsidies divided by the overall costs of subsidies, ignoring the shadow cost of taxes.

increase in the applicants' gross profits due to expected subsidies is substantially less than the median increase in the non-applicants' profits (46 000 euros vs. 206 000 euros). A comparison of the figures with the private returns without subsidies, however, shows that the relative increase is higher for applicants than non-applicants. The non-applicants' projects also generate higher median increase in the agency specific utility than the applicants' projects (77 000 euros and 19 000 euros respectively). Figure 2 displays the distribution of the gross treatment effect for both applicants (left graph) and non-applicants (right graph) using expected subsidies as the treatment. It is evident that non-applicants' treatment effects are larger on average and that there is substantial heterogeneity.

[FIGURE 2 HERE]

We have also calculated rates of return on expected subsidies, again ignoring application costs. The rates of return in case of subsidized applicants are higher with expected subsidies than with actual ones, because some applicants, who would have generated very high returns if they had received expected subsidies, received lower subsidies and therefore generate lower returns. The rate of return on the subsidy program using the expected subsidy is 1.39 for applicants and the same for non-applicants. The median joint rate of return on expected subsidy is 1.38 for applicants and 1.37 for non-applicants.

The private and agency, and therefore, joint expected treatment effects are substantially lower for applicants, while the joint rates of return are similar for applicants and non-applicants. The reason why applicants' projects are submitted to Tekes is that they involve much lower application costs than the projects that are not submitted. The median costs of application is 34 000 euros for applicants compared to 2 million euros for non-applicants. This is generated by the positive correlation between the shock to the marginal profitability of R&D and the application cost shock. Some privately and jointly profitable projects thus have very high private opportunity costs of applying.

C Distribution of returns

In the following we assume that *V*( ) reflects returns to the Finnish society that are not appropriated by the firm. It is of course questionable whether Tekes' decisions reflect social returns or not. However, for the sake of the argument, let us proceed under that assumption. As mentioned, even if this is the case, *V*( ) does not measure the global social surplus: it is very likely that most of the consumer surplus and at least some of the spillovers stemming from Finnish innovations will diffuse outside Finland. Therefore, one can think that *V*( ) mainly consists of domestic technological spillovers. This interpretation is supported by our observation that technical challenge ratings gain a significant role in the Tekes decision rule.

We first discuss how agency specific returns vary with R&D investments. This immediately yields the variation of the agency specific returns with subsidies, given the complementarity of the investment and subsidy levels in our model. We then describe and characterize the joint distribution of private and agency specific benefits from R&D. Much of the growth and R&D spillover literatures assume that spillovers are increasing in R&D: Studying the distribution of agency specific returns allows us to test this assumption in our data. The joint distribution in turn is central in uncovering whether the social returns of R&D grow in proportion to private returns or not.

Recall that we can estimate the profits from a firm's R&D project conditional on its decision to apply for a subsidy (E[Π( )|*X*, *d*]), and the agency specific utility from the project (E[*V*]=E[$Z\hat{\delta}$]E[*R*]). As before, in calculating E[$Z\hat{\delta}$], we set $\underline{g}$=1.2 and $F_i=K_i$, yielding -0.14 as our estimate of the constant. Using this value, E[$Z\hat{\delta}$] is nonnegative for 97% of our observations: Figure 3 depicts the distribution of E[$Z\hat{\delta}$]. This implies that E[*V*( )] is increasing in R&D investments and, hence, in the subsidy rate, for almost all projects in our data. The figure also reveals that for most projects, the expected increase in spillovers is between 0.25 and 0.5 per one euro of R&D. For 99% of firms, a one euro increase in R&D leads to a less than 0.7 euro increase in spillovers.[38]

[FIGURES 3 AND 4 HERE]

Figure 4 presents the joint distribution of private and agency specific returns, and a non-parametric estimate of E[*V*( )] as a function of E[Π( )|X, *d*].[39] Regressing E[*V*( )] on E[Π( )|X, *d*] and a constant yields a highly significant coefficient of 0.022, while the raw correlation is 0.875 and significant at the 1% level. The estimated nonparametric relationship between the agency specific and private returns seems to be almost linear for most of the interval.

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[38] We trimmed the sample used in Figure 3 at the 99th percentile.

[39] We have trimmed the sample at the 95th percentile to aid the visualization of the distribution. The estimate is a *k*-nearest neighbor estimate.

VII Conclusions

We develop a new approach to characterize the determinants and the distribution of R&D returns, to measure treatment effects and to improve our understanding of how an R&D subsidy program works. The method exploits a structural treatment program model and firm and R&D project level data. We find that spillover and profitability shocks are unrelated and spillovers are linear in R&D investments. The returns appropriated by the agency but not by the firm are dominated by private returns. Both private and social rates of return to R&D investment are large and their distribution skew. Large firms' projects yield higher agency specific returns. Profitability and application cost shocks are positively related, implying that firms do not apply for subsidies for the privately most profitable projects.

On the treatment effect side we are able to extend the number of identified treatment effects. We find considerable heterogeneity in all of them, generated both through observables and unobservables. We also compare the expected effects of subsidies between non-applicants and applicants had the non-applicants and the applicants been granted the anticipated subsidy. The findings indicate that both the private and the agency treatment effects are substantially lower for applicants, while the expected joint rates of return are similar for applicants and non-applicants. In general, our results suggest that ignoring application costs is recommendable neither in the research of R&D subsidy treatment effects nor in practical policy making, as it leads to a significant upward bias. For example, the median increase in the subsidized applicants' profits due to subsidies is 30 000€, while the corresponding figure ignoring application costs is 65 000€.

REFERENCES

Blanes, J., and Busom. I., 2004, Who participates in R&D subsidy programs? The case of Spanish manufacturing firms, Research Policy, 33, 1459-1476.

Blundell, R., and Costa-Dias, M., 2002, Alternative approaches to evaluation in empirical microeconomics, Portuguese Economic Journal, 1, 91-115.

Blundell, R., and MaCurdy, T., 1999, Labor supply: A review of alternative approaches, in Ashenfelter, O., and Card, D. (eds.), Handbook of Labor Economics, 3, Amsterdam: North-Holland.

Bjorklund, A., and Moffitt, R., 1987, The estimation of wage gains and welfare gains in self-selection models, The Review of Economics and Statistics, 69, 42-49.

Cameron, S., and Taber, C., 2004, Estimation of educational borrowing constraints using returns to schooling, Journal of Political Economy, 112, 132-182.

Cohen, W., 1995, Empirical studies of innovative activity, in Stoneman, P. (ed.), Handbook of the Economics of Innovation and Technological Change, Basil Blackwell.

Das, M., Newey, W., and Vella, F., 2003, Nonparametric estimation of sample selection models, Review of Economic Studies, 70, 33-58.

David, P., Hall, B., and Toole, A., 2000, Is public R&D a complement or a substitute for private R&D? A review of the econometric evidence, Research Policy, 29, 497-529.

Davidson, C., and Woodbury, S., 1993, The displacement effect of unemployment bonus programs, Journal of Labor Economics, 20, 380-388.

Dehejia, R., 2005, Program evaluation as a decision problem, Journal of Econometrics, 125, 141-173.

Eaton, J., and Kortum. S., 2002, Technology, geography, and trade, Econometrica, 70, 1741-1779.

Gagnepain, P., and Ivaldi, M., 2002, Incentive regulatory policies: The case of public transit systems in France, RAND Journal of Economics, 33, 1-25.

Georghiu, L., Smith, K., Toivanen, O., and Ylä-Anttila, P., 2003, Evaluation of the Finnish innovation support system, Finland’s Ministry of Trade and Industry, publications 5/2003.

González, X., C. Pazó and Jaumandreau, J., 2005, Barriers to innovation and subsidy effectiveness, RAND Journal of Economics, 36, 930-950.

Griliches, Z., 1958, Research costs and social returns: Hybrid corn and related innovations, Journal of Political Economy, 66, 419-431.

Griliches, Z., 1964, Research expenditures, education, and the aggregate agricultural production function, American Economic Review, 54, 961-974.

Griliches, Z., 1998, R&D and productivity: The econometric evidence, The University of Chicago Press.

Hall, B. 2002, The financing of research and development, Oxford Review of Economic Policy, 18, 35-51.

Heckman, J., 1997, Instrumental variables: A study of implicit behavioral assumptions used in making program evaluations, Journal of Human Resources, 32, 441-462.

Heckman, J., Lalonde, R., and Smith, J., 1999, The Economics and Econometrics of Active Labor Market Policies, in Ashenfelter, O., and Card, D. (eds), Handbook of Labor Economics, Amsterdam: North-Holland.

Heckman, J., Lochner, L., and Taber, C., 1998, General-equilibrium treatment effects: A study of tuition policy, American Economic Review, Papers and Proceedings, 88, 381-386.

Heckman, J., and Robb, R., 1985, Alternative methods for evaluating the impact of interventions, in Heckman, J., and Singer, B. (eds.), Longitudinal Analysis of Labor Market data, Econometric Society Monographs, 10, Cambridge:

Heckman, J., and Smith, J., 1995, Assessing the case for social experiments, Journal of Economic Perspectives, 9, 85-110.

Heckman, J. and Smith, J. 2004, The determinants of participation in a social program: Evidence from a prototypical job training program, Journal of Labor Economics, 22, 243-298.
Heckman, J., Smith, J., and Taber, C., 1996, What do bureaucrats do? The effects of performance standards and bureaucratic preferences on acceptance into the JTPA program, in Liebcap, G. (ed.), Advances in the Study of Entrepreneurship, Innovation and Growth, 7, 191-217, JAI Press.
Henderson, R., and Cockburn, I., 1996, Scale, scope and spillovers: The determinants of research productivity in drug discovery, RAND Journal of Economics, 27, 1, 32-59.
Howitt, P., 1999, Steady endogenous growth with population and R&D inputs growing, Journal of Political Economy, 107, 715-730.
Hyytinen, A. and Pajarinen, M., 2003, Financial systems and firm performance: Theoretical and empirical perspectives, Taloustieto Ltd., Helsinki.
Imbens, G., 2000, The role of propensity score in estimating dose-response functions, Biometrika, 87, 706-710.
Jaffe, A., 2002, Building programme evaluation into the design of public research-support programmes, Oxford Review of Economic Policy, 18, 22-34.
Jovanovic, B., and Eeckhout, J., 2002, Knowledge spillovers and inequality, American Economic Review, 92, 5, 1290-1307.
Keane, M., and Moffit, R., 1998, A structural model of multiple welfare program participation and labor supply, International Economic Review, 39, 3, 553-589.
Keane, M., and Wolpin, K., 2001, The effect of parental transfers and borrowing constraints on educational attainment, International Economic Review, 42, 4, 1051-1103.
Klette, T., Møen, J., and Griliches, Z., 2000, Do subsidies to commercial R&D reduce market failures? Microeconomic evaluation studies, Research Policy, 29, 471-495.
Kuismanen, M., 2000, Labour supply and income tax changes: a simulation study for Finland, Bank of Finland Discussion paper, 5/2000.
Lanjouw, J., 1998, Patent protection in the shadow of infringement: Simulation estimations of patent value, Review of Economic Studies, 65, 4, 671-710.
Lechner, M., 2001, Identification and estimation of causal effect of multiple treatments under the conditional independence assumption, in Lechner, M., and Pfeiffer, F. (eds), Econometric Evaluation of Labour Market Policies, 43-58, Heidelberg: Physica/Springer.
Lerner, J., 1999, The government as a venture capitalist: The long-run impact of the SBIR program, Journal of Business, 72, 3, 285-318.
Levin, and Reiss, P., 1988, Cost-reducing and Demand-creating R&D with spillovers, RAND Journal of Economics, 19, 4, 538-556.
Maddala, G., 1983, Limited-dependent and qualitative variables in econometrics, Econometric Society Monograph No. 3., Cambridge.
Mansfield, E., Rapoport, J., Romeo, A., Wagner, S., and Beardsley, G., 1977, Social and private rates of return from industrial innovation, Quarterly Journal of Economics, 91, 2, 221-240.
Manski, C., 1989, The anatomy of the selection problem, Journal of Human Resources, 24, 343-360.
Manski, C., 2000, Identification problems and decision under ambiguity: Empirical analysis of treatment response and normative analysis of treatment choice, Journal of Econometrics, 95, 415-442.
McFadden, D., 1975, The revealed preferences of a government bureaucracy: Theory, Bell Journal of Economics, 6, 401-416.
McFadden, D., 1976, The revealed preferences of a government bureaucracy: Empirical evidence, Bell Journal of Economics, 7, 55-72.
Nevo, R., 1998, Trends and Patterns of Public Support to Industry in the OECD Area, STI Review, 21, 12-24.

Pakes, A., 1986, Patents as options: Some estimates of the value of holding European patent stocks, Econometrica, 57, 755-784.

Petrin, A., 2002, Quantifying the benefits of new products: The case of the Minivan, Journal of Political Economy, 110, 705-729.

Powell, J., 1984, Least absolute deviations estimation for the censored regression model, Journal of Econometrics, 25, 303-325.

Pretschker, U., 1998, Public support to industrial R&D efforts, STI Review, 21, 91-104.

Reiss, P., and Wolak, F., 2004, Structural econometric modeling: Rationales and examples from Industrial Organization, forthcoming in Heckman J., and Leamer, E. (eds.), Handbook of Econometrics, 6, Amsterdam: North-Holland.

Roberts, B., Maddala, G., and Enholm, G., 1978, Determinants of the requested rate of return and the rate of return granted in a formal regulatory process, Bell Journal of Economics, 9, 611-621.

Scherer, F., and Harhoff, D., 2000, Technology policy for a world of skew-distributed outcomes, Research Policy, 29, 559-566.

Segerstrom, P., 2000, The Long-Run Growth Effects of R&D Subsidies, Journal of Economic Growth, 5, 3, 277-305.

Trajtenberg, M., 2001, Innovation in Israel 1968-1997: A comparative analysis using patent data, Research Policy, 30, 363-389.

Udry, C., and Anagol, S., 2006, The return to capital in Ghana, American Economic Review, Papers and Proceedings, 96, 388-393.

Wallsten, S., 2000, The effects of government-industry R&D programs on private R&D: The case of the Small Business Innovation Research Program, RAND Journal of Economics, 31, 82-100.

Willis, R., and Rosen, S., 1979, Education and self-selection, Journal of Political Economy, 87, 5, S7-S36.

Wolak, F., 1994, An econometric analysis of the asymmetric information regulator-utility interaction, Annales d'Economie et de Statistique, 34, 13-69.

Yatchew, A., 1998, Nonparametric regression techniques in economics, Journal of Economic Literature, 36, 669-721.

Table 1
Descriptive Statistics

	Mean	S.d.	Min.	Max.
Age, years	12.320	9.3453	1	97
# Employees	35.229	257.174	1	13451
Sales/employee, 1000 euros	164.920	2156.961	0	206875.5
Exporter	0.063	0.244	0	1
SME	0.975	0.157	0	1
CEO is chairman of board	0.141	0.348	0	1
Board size	4.350	2.003	1	10
# past Tekes applications	0.575	3.488	0	146
Applicant	0.084	0.277	0	1

NOTES: There are 10944 observations. Data sources: Asiakastieto Ltd. otherwise; for data on applications, Tekes.

Table 2
Conditional Descriptive Statistics

	Non-Applicants	Applicants	Rejected Applicants	Successful Applicants
Age	12.355	11.940	11.777	11.983
	(9.326)	(9.557)	(9.964)	(9.452)
	[10]	[10]	[9]	[10]
# Employees	21.200	189.001	101.269	212.453
	(122.282)	(775.862)	(187.503)	(866.674)
	[5]	[26]	[21]	[27]
Sales/employee	168.852	121.826	104.831	126.369
	(2252.692)	(54.996)	(94.238)	(167.307)
	[77.55]	[89.72]	[82.95]	[91.58]
Exporter	0.059	0.109	0.119	0.107
	(0.236)	(0.312)	(0.325)	(0.309)
SME	0.9860	0.850	0.855	0.849
	(0.1173)	(0.357)	(0.352)	(0.358)
CEO is chairman of board	0.141	0.149	0.176	0.141
	(0.348)	(0.356)	(0.382)	(0.349)
Board size	4.183	6.177	5.850	6.265
	(1.873)	(2.431)	(2.285)	(2.462)
	[4]	[6]	[5]	[6]
# past Tekes applications	0.247	4.163	3.228	4.413
	(1.283)	(10.657)	(10.933)	(10.576)
	[0]	[2]	[1]	[2]
Nobs.	10029	915	193	722

NOTES: Number reported are mean, (standard deviation), and for other than [0,1] variables, [median]. Data sources: Asiakastieto Ltd. otherwise; for data on applications, Tekes.

Table 3
Descriptive Statistics of Tekes and Application Variables

	All Applicants	Successful Applicants	Rejected Applicants
Applied amount, euros	634294 (1254977)	700378.2 (1363460)	385790 (657539.8)
Applied for subsidy only	0.591 (0.492)	0.482 (0.500)	1.000 (0.000)
Technical challenge	2.088 (0.982) {582}	2.312 (0.872) {426}	1.474 (1.006) {156}
Risk	2.189 (0.937) {422}	2.150 (0.925) {326}	2.302 (0.937) {96}
Granted subsidy rate	-	0.316 (0.126)	-
Granted subsidy only	-	0.839 (0.600)	-
Nobs.	915	722	193

NOTES: Datasource: Tekes. Reported numbers are mean, standard deviation, and {nobs}, the last in case it deviates from that reported on the last row.

Table 4
Tekes Decision Rule Results

Variable	(1) ML Dep. var. subsidy-intensity (all finance)	(2) CLAD Dep. var. subsidy-intensity. (all finance)	(3) ML Dep. var. subsidy-intensity (subsidies only)
Risk	-.018	-.020**	-.019
	[-.041 .005]	[-.039 -.001]	[-.048 .009]
Technical challenge	.100***	.094***	.120**
	[.076 .124]	[.074 .113]	[.090 .150]
Age	-.001	.0003	-.001
	[-.003 .001]	[-.0017 .0023]	[-.004 .002]
Log employment	.0164*	.024***	.031***
	[-.003 .036]	[.008 .040]	[.007 .055]
Sales / employment	.000036	.000034	.000036
	[-.000136 .000276]	[-.000083 .000151]	[-.00017 .000243]
SME	.085*	.068*	.093*
	[-.001 .170]	[-.003 .138]	[-.011 .197]
Parent company	.006	.016	.014
	[-.040 .053]	[-.023 .055]	[-.043 .070]
# previous applications	-.001	-.002	-.003
	[-.006 .004]	[-.006 .002]	[-.009 .003]
CEO also chairman	.001	-.018	-.013
	[-.053 .055]	[-.064 .028]	[-.080 .055]
Board size	-.007	-.0001	-.009
	[-.017 .003]	[-.0084 .0082]	[-.021 .003]
Exporter	-.042	-.016	-.079*
	[-.107 .023]	[-.069 .038]	[-.161 .002]
Constant	-.060	-.103	-.197**
	[-.217 .098]	[-.233 .028]	[-.393 -.001]
σ_η	.189***	-	.225***
	[.173 .206]		[.203 .247]
Nobs.	379	379	379
LogL.	-18.636	-	-91.763
Wald	0.000	-	0.000
Linearity 1	0.690	-	-
Linearity 2	0.313	-	-
Sample sel.	.068	-	-
	(.051)		

NOTES: Reported numbers are coefficient and [95% confidence interval]. Wald is the p-value of a Wald test of joint significance of all RHS variables. All specifications include industry and region dummies.
Linearity 1 = the p-value of a LR-test of including the proposed R&D investment into the equation.
Linearity 2 = the p-value of a LR-test of including the proposed R&D investment into the equation, plus interactions between it and age, log employment, and sales/employee.
Sample sel. = coeff. and (s.e.) of the Mills ratio term when the 1(apply) specification same as in Table 5.
***, **, and * denote significance at 1, 5, and 10% level.
In columns (1) and (2), the dependent variable is the proportion of expenses that the Agency covers, defined as the sum of all three types of financing the Agency grants (in euros, see main text) divided by accepted proposed investment. In column (3), the dependent variable is the subsidy (in euros) divided by the accepted proposed investment.

Table 5
Application Cost Function Results

Variable	Value
Age	.008
	[-.015 .630]
Age sq.	4.413e-05
	[-.006 .0004]
Log of employment	-.293**
	[-15.151 -.014]
Ln(emp) sq.	.040**
	[.008 1.497]
Sales/employee	.002*
	[-.0003 .014]
Sales/emp. Sq.	-1.974e-0.7
	[-8.11e-07 3.69e-06]
SME	.093
	[-2.334 3.488]
Parent company	-.085
	[-6.661 .128]
# Previous applications	-.171***
	[-6.606 -.078]
# Prev appl. sq.	.001***
	[.0006 .051]
CEO is chairman	-.285
	[-1.550 .409]
Board size	-.075**
	[-3.032 -.008]
Exporter	-.598**
	[-10.405 -.090]
Constant	13.110***
	[11.156 100.589]
Nobs	10751
LogL.	-18.636
Wald (d.f. 29)	0.000

NOTES: Reported numbers are coefficient and [95% confidence interval]. Statistics refer to the probit 1st stage regression from the results of which the cost function coefficients have been backed out. Confidence intervals are estimated using a bootstrap with 400 repetitions. The specification includes industry and regional dummies.

Wald is the p-value of the joint significance of all explanatory variables in the probit 1st stage regression.

***, **, *, and [a] denote that the whole 99%, 95%, 90% and 85% confidence interval has the same sign as the coefficient estimate.

Table 6
R&D Investment Function Results

Variable	(1) ML Dep. var. accepted proposed investment	(2) ML Dep. var. accepted proposed investment	(3) DNV Dep. var. accepted proposed investment	(4) ML Dep. var. proposed investment
Age	-.005	.002	.0001	-.005
	[-.025 .012]	[-.007 .007]	[-.030 .025]	[-.027 .006]
Age sq.	.0002	-	.0002	.0001
	[-.00008 .0005]		[-.0002 .0005]	[-.00008 .0004]
Log of	-.077	.041**	-.024	-.130
employment	[-.226 .132]	[.014 .159]	[-.362 .327]	[-.268 .206]
Ln(emp) sq.	.015	-	-.001	.022
	[-.021 .038]		[-.039 .036]	[-.017 .040]
Sales/empl.	.001**	0.0009***	.001**	.001*
	[.00002 .002]	[.0005 .002]	[.0003 .003]	[-.00003 .002]
Sales/emp.	-1.95e-07	-	-2.9e-07	-1.53e-07
sq.	[-7.74e-07 1.28e-06]		[-1.01e-06 1.33e-06]	[-6.27e-07 1.66e-06]
SME	-.258	-.280	-.011	-.063
	[-.726 .166]	[-.523 .096]	[-.766 .815]	[-.511 .349]
Parent	.020	.064	-.091	-.035
company	[-.166 .208]	[-.072 .271]	[-.438 .236]	[-.183 .182]
# Previous	-.047**	-.007	-.295	-.047[a]
applications	[-.082 -.013]	[-.018 .004]	[-.748 .174]	[-.070 .006]
# Prev appl.	.0003**	-	.002	.0003
sq.	[.0001 .0013]		[-.005 .011]	[-.0001 .0007]
CEO is	-.182*	-.194**	-.158	-.107
chairman	[-.354 .022]	[-.366 -.011]	[-.368 .066]	[-.290 .100]
Board size	-.008	.008	-.065	.007
	[-.038 .036]	[-.015 .056]	[-.207 .086]	[-.020 .063]
Exporter	-.255*	-.199	-.398	-.118
	[-.455 .0029]	[-.355 .047]	[-.849 .162]	[-.258 .173]
Propensity	-	-	-13.363[a]	-
score			[-28.604 3.440]	
Constant	13.234***	12.416***	-	13.002***
	[11.909 14.123]	[10.950 12.734]		[10.923 13.536]
Nobs.	722	722	688	914
Wald (d.f. X)	0.000	0.000	0.000	0.000
$\ln(1-\bar{s})$	0.158			-0.718
	(0.181)			(0.740)

NOTES: Reported numbers are coefficient and [95% confidence interval]. Confidence intervals are based on a bootstrap with 400 repetitions. In columns (1)-(3) the dependent variable is the log of accepted proposed investment: in column (4) it is the log of proposed investment.

Wald is the p-value of joint significance of RHS variables. The constant is not identified when using DNV.

$\ln(1-\bar{s})$ coefficient reports the coefficient and the (p-value) of a χ^2 -test of difference from unity. The SME dummy was excluded from the test regressions due to collinearity with $\ln(1-\bar{s})$.

***, **, *, and [a] denote that the whole 99%, 95%, 90% and 85% confidence interval has the same sign as the coefficient estimate.

Table 7
Covariance Structure Results

Variable	Value
σ_{ε} Standard deviation of the investment equation shock	1.120*** [.834 1.256]
σ_{η} Standard deviation of the Tekes specific utility (=V( )) shock	.189*** [.173 .206]
$\sigma_{\upsilon 0}$ Standard deviation of the uncorrelated part of the application cost function shock	.456*** [.111 12.552]
$1+\rho$ Measure of the variance share of ε in υ	1.485*** [1.052 11.010]
$\rho_{\varepsilon\upsilon}$ Correlation between ε and the application equation error term	-.766*** [-.879 -.153]

NOTES: Reported numbers are coefficient and [95% confidence interval]. For all but σ_{η} , these are based on a bootstrap with 400 repetitions. For σ_{η} , it is based on the estimated covariance matrix. ***, **, and * denote significance at 1, 5, and 10% level.

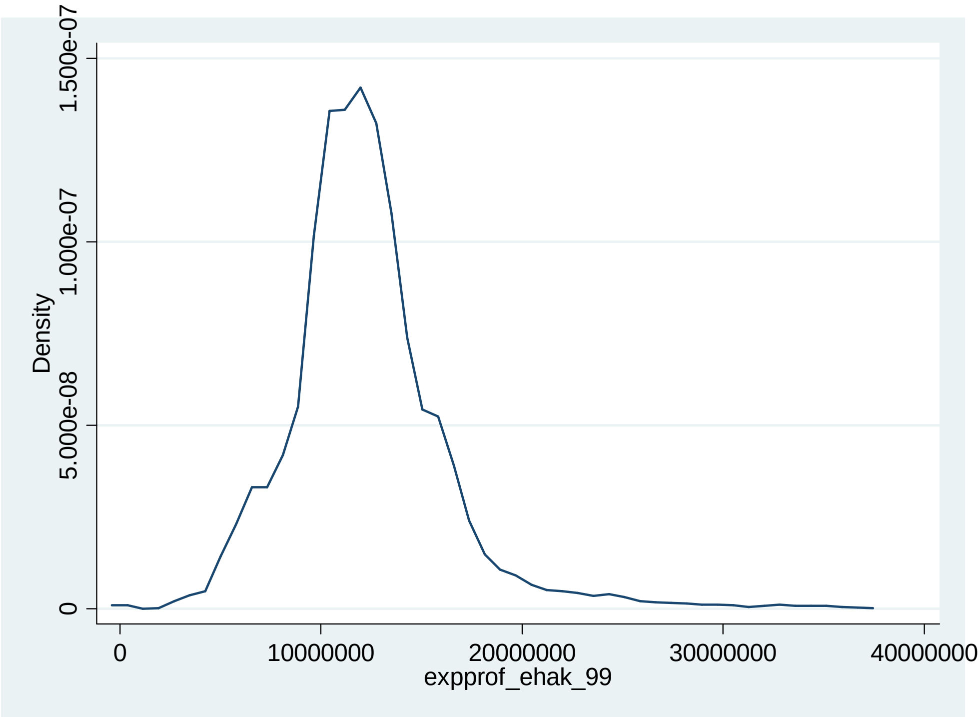

Figure 1: Distribution of expected discounted profits of non-applicants (with no subsidies).

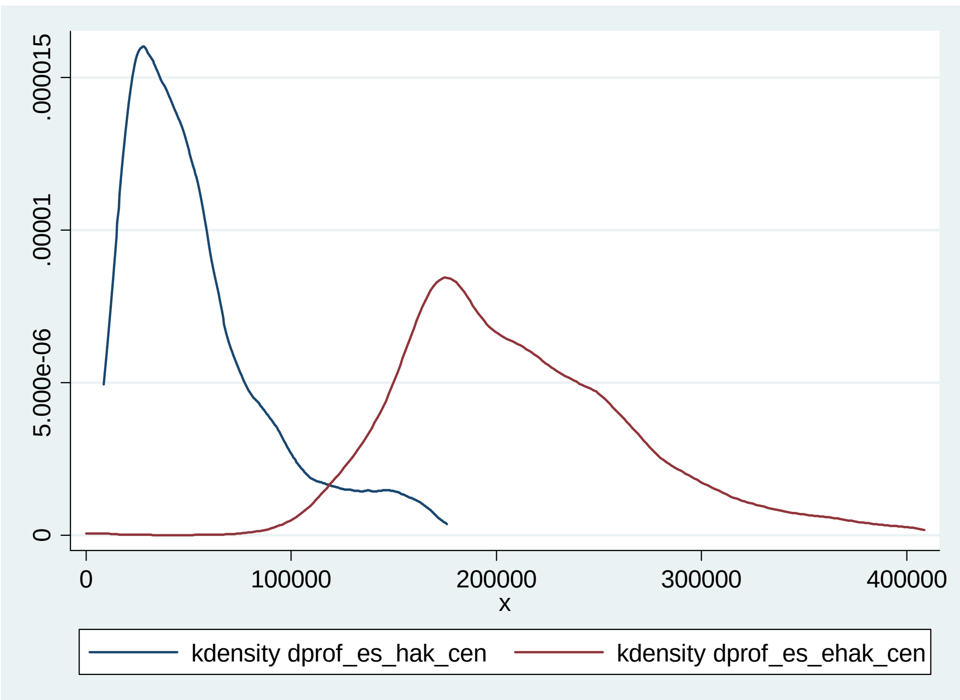

Figure 2: Distribution of the treatment effect for applicants (left graph) and non-applicants using expected subsidies as the treatment.

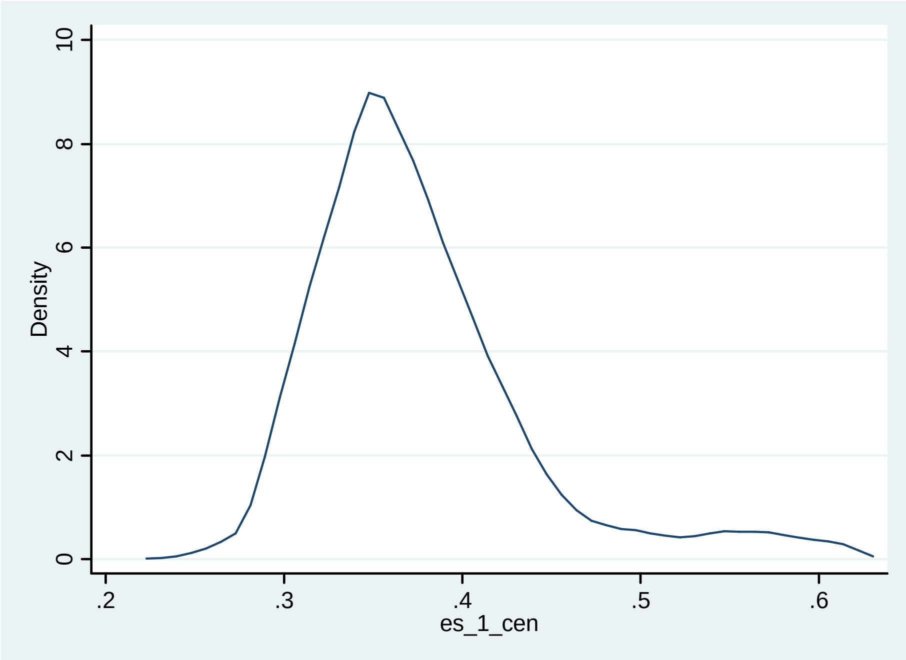

Figure 3: Distribution of E[$Z\hat{\delta}$].

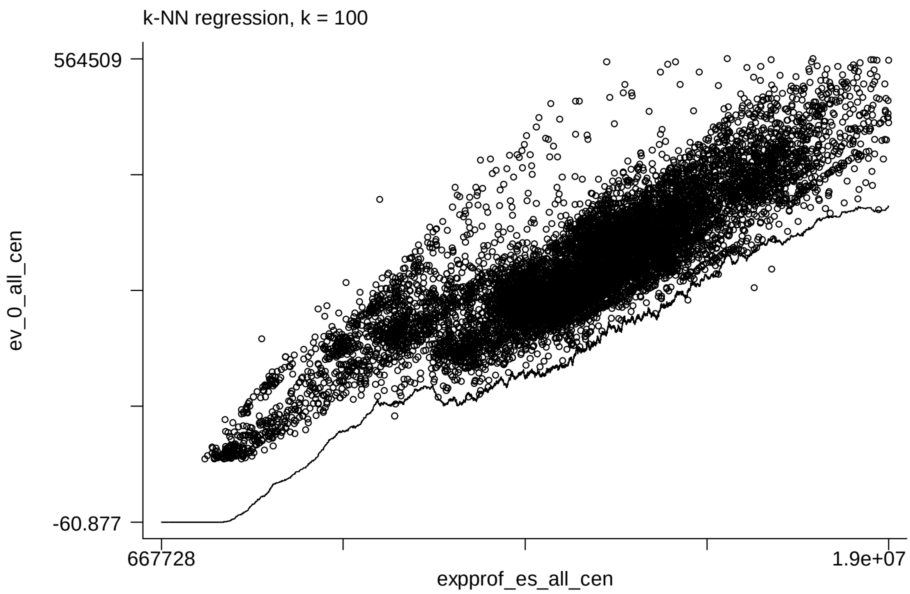

Figure 4: Joint distribution of expected discounted private and joint benefits from R&D w/o subsidies, all firms.

APPENDIX A

In this Appendix, we report the ordered probit estimation of the Tekes grading process; descriptive statistics of a) the whole application sample b) the application sample who have strictly positive accepted proposed investments, and c) the application sample for which we observe grades in both evaluation dimensions; industry and region dummy descriptive statistics and their coefficients for the estimated equations; and the cross-validation figures for the 1^{st} and 2^{nd} stage DNV estimations.

We have different applicant samples in the estimations of the two grading dimensions, because sometimes we only observe one or the other grade for an application. During our observation period, Tekes did not uniformly store grading data in their central database, from which our data has been collected. We use the estimation results to create the probabilities of getting a particular grade for all the 10751 (10944) observations in the estimation sample.

A.1 The evaluation equations

In the technical challenge estimation, sales per employee, number of previous applications, board size, and industry dummies (chemical, industry, electric engineering, data processing, and R&D services) increase the probability of getting a high grade in evaluation of technical challenge. Having a CEO as chairman and being in the food or paper industry decreases the probability of getting a high grade.

In the market risk estimation, sales per employee and a number of industry dummies have a negative effect on the probability of obtaining a high risk rating (high meaning higher risk). The industry dummies that carry significant negative coefficients are paper, other manufacturing, and telecoms. Being located in Western Finland also decreases the probability of being classified as high risk.

Table A.1
Estimation of the Evaluation Equations

Variable	Technical Challenge	Risk
Age	.003	-.0042379
	[-.007 .013]	[-.0164625 .0079868]
Log Employees	.008	-.0536393
	[-.076 .092]	[-.1538962 .0466177]
Sales/employee	.001***	-.0008665*
	[.0002 .002]	[-.0017846 .0000516]
SME	-.101	.0600485
	[-.476 .274]	[-.3851782 .5052751]
Parent Company	-.002	-.1378355
	[-.206 .202]	[-.3769572 .1012863]
# Previous	.021*	-.0189169
Applications	[-.003 .044]	[-.045992 .0081582]
CEO is chairman	-.247**	-.0118448
	[-.487 -.006]	[-.2940517 .270362]
Board size	.078	.0331881
	[.034 .121]	[-.0160126 .0823889]
Exporter	.170	.2292716
	[-.114 .454]	[-.1084814 .5670247]
Nobs.	582	422
LogL.	-753.92882	-528.7958
Joint Significance	0.000	0.0000

NOTES: reported numbers are coefficient and [95% confidence interval]. Joint Significance is the p-value of a LR test of joint significance of all explanatory variables. Both specifications include industry and region dummies.
***, **, and * denote significance at 1, 5, and 10% level.

A.2 Descriptive statistics of the applicant samples

Table A.2 presents the descriptive statistics for the three samples of applicants mentioned above. As can be seen, the differences are minor; judging on observables, we are unlikely to have a selection problem among applicants in the subsidy equation. The only potentially worrisome difference is that in the smallest sample, the mean number of previous application is lower (2.8) than in the other two (4.2 and 4.4). The standard error also declines. Also, the proportion of telecom firms and firms in Eastern Finland are somewhat lower. As we report in the main text, we found no evidence for sample selection after testing it against the whole sample.

Table A.2
Descriptive Statistics of Different Applicant Samples

Variable	All Applicants	Applicants with strictly positive proposed accepted investment	Applicants for whom grades in both evaluation dimensions are observed
Age	11.940	11.983	11.425
	(9.557)	(9.452)	(8.961)
Log Employees	3.416	3.469	3.213
	(1.787)	(1.786)	(1.684)
Sales/employee	121.826	126.369	120.252
	(154.996)	(167.307)	(128.096)
SME	.850	.849	.879
	(.357)	(.358)	(.327)
Parent company	.510	.525	.478
	(.500)	(.500)	(.500)
# Previous applications	4.163	4.413	2.765
	(10.657)	(10.576)	(4.545)
CEO is chairman	.149	.141	.174
	(.356)	(.349)	(.380)
Board size	6.177	6.265	6.090
	(2.431)	(2.462)	(2.367)
Exporter	.109	.107	.116
	(.312)	(.309)	(.321)
Food	.035	.037	.032
	(.184)	(190)	(.175)
Paper	.051	.051	.037
	(.221)	(.221)	(.189)
Chemicals	.032	.035	.026
	(.175)	(.183)	(.160)
Rubber	.062	.061	.061
	(.242)	(.239)	(.239)
Metals	.079	.080	.069
	(.269)	(.272)	(.253)
Electric	.101	.108	.106
	(.301)	(.311)	(.308)
Radio and TV	.040	.039	.047
	(.197)	(.193)	(.213)
Other manufacturing	.093	.091	.087
	(.290)	(.288)	(.282)
Telecoms	.009	.010	.003
	(.093)	(.098)	(.051)
Data processing	.207	.197	.259
	(.405)	(.398)	(.438)
R&D	.148	.147	.129
	(.355)	(.354)	(.336)
Western Finland	.321	.321	.351
	(.467)	(.467)	(.478)
Eastern Finland	.115	.125	.058
	(.319)	(.331)	(.234)
Central Finland/ Oulu	.085	.079	.087
region	(.279)	(.270)	(.282)
Northern Finland /	.022	.019	.029
Lapland region	(.146)	(.138)	(.168)
Nobs.	915	722	379

A.3 Descriptive statistics of the industry and region dummies for the whole sample

Table A.3
Descriptive Statistics of the Industry and Region Dummies for the Whole Sample

Indicator	Mean (s.d.)
Agriculture	.0001
	(.010)
Food	.045
	(.207)
Paper	.061
	(.239)
Chemicals	.015
	(.120)
Rubber	.056
	(.229)
Metals	.139
	(.346)
Electric	.046
	(.209)
Radio and TV	.015
	(.120)
Other manufacturing	.188
	(.391)
Telecoms	.009
	(.095)
Data processing	.105
	(.307)
R&D	.196
	(.397)
Southern Finland	.453
	(.498)
Western Finland	.386
	(.487)
Eastern Finland	.078
	(.268)
Central Finland/Oulu region	.061
	(.240)
Northern Finland/Lapland	.023
	(.149)

NOTES: there are 10944 observations.

A.4 Coefficients of industry and region dummies

Table A.4
Estimated Industry and Region Dummy Parameters

Variable	Tekes Decision Rule Table 4			Application Cost Function Table 5	R&D Investment Function Table 6			
Column	(1)	(2)	(3)		(1)	(2)	(3)	(4)
Food	.246***	.241***	.312***	.045	-.649***	-.612***	-.518*	-.522***
	[.122 .370]	[.137 .345]	[.163 .461]	[-1.593 3.204]	[-1.012 -.265]	[-1.00 -.269]	[-.968 .025]	[-.884 -.155]
Paper	-.017	.018	.0003	.070	.034	.017	.144	.183
	[-.140 .106]	[-.080 .116]	[-.1488 .1494]	[-0.632 10.919]	[-.354 .364]	[-.350 .343]	[-.395 .808]	[-.203 .482]
Chemicals	.094	.052	.132	.759	.213	.264	.232	.163
	[-.039 .228]	[-.060 .164]	[.029 .292]	[-10.372 1.601]	[-.253 .744]	[-.162 .752]	[-.573 .889]	[-.320 .723]
Rubber	.012	.080	.008*	.191	.099	.103	.109	.080
	[-.084 .108]	[-.002 .162]	[-.111 .126]	[-.479 5.275]	[-.228 .406]	[-.213 .407]	[-.214 .542]	[-.254 .420]
Metals	.004	.013	-.014	.335[a]	.248*	.231a	.289	.403**
	[-.089 .095]	[-.063 .089]	[-.128 .100]	[-.142 8.231]	[-.030 .499]	[-.067 .472]	[-.127 .708]	[.023 .637]
Electric	-.046	-.006	-.052	-.105	.111	.167*	-.078	.254**
	[-.128 .036]	[-.076 .063]	[-.153 .050]	[-13.195 .360]	[-.178 .458]	[-.030 .540]	[-.678 .593]	[.036 .641]
Radio and TV	-.029	.011	-.001	.508	.594***	.621***	.486*	.603**
	[-.137 .078]	[-.077 .100]	[-.131 .128]	[-5.121 1.552]	[.191 1.177]	[.247 1.183]	[-.066 1.287]	[.126 1.223]
Other manufacturing	-.019	.013	-.016	.204	.014	-.045	.0002	.205
	[-.107 .069]	[-.060 .086]	[-.123 .092]	[-.332 9.556]	[-.280 .299]	[-.379 .217]	[-.391 .460]	[-.185 .433]
Telecoms	-	-	-	.920*	.580*	.520*	.888*	.602
				[-.055 14.543]	[-.072 1.262]	[-.084 1.08]	[-.221 2.095]	[-.101 1.226]
Data processing	-.066*	-.028	-.058	-.285	.079	.174*	-.199	.210**
	[-.140 .008]	[-.090 .033]	[-.150 .034]	[-17.328 .245]	[-.162 .390]	[-.029 .484]	[-.917 .552]	[.027 .605]
R&D	.007	.049	.024	.111	.-0.52	-.074	-.071	.096
	[-.073 .087]	[-.018 .117]	[-.075 .122]	[-.998 1.739]	[-.340 .224]	[-.286 .226]	[-.353 .251]	[-.184 .367]
Western Finland	.018	.026	.019	.304	.160**	.151**	.147*	.236***
	[-.028 .064]	[-.012 .065]	[-.038 .075]	[-.802 .770]	[.013 .342]	[.012 .328]	[-.011 .321]	[.079 .418]
Eastern Finland	.096**	.088**	.145***	-.262[a]	-.427***	-.374***	.539**	-.462***
	[.007 .185]	[.014 .162]	[.037 .252]	[-11.514 .172]	[-.644 -.128]	[-.548 -.059]	[-.980 -.030]	[-.622 -.094]
Central Finland/Oulu region	.069*	.031	.102**	.052	-.057	-.033	-.175	.062
	[-.006 .145]	[-.030 .092]	[.010 .193]	[-5.856 .547]	[-.291 .261]	[-.246 .255]	[-.600 .242]	[-.175 .369]
Northern Finland/Lapland	-.031	-.026	-.014	.194	.257	.280a	.245	.096
	[-.158 .095]	[-.121 .070]	[-.170 .142]	[-2.989 2.085]	[-.095 .715]	[-.027 .715]	[-.188 .702]	[-.190 .507]

NOTES: in the Tekes decision rule equations, we excluded the telecommunications dummy because of problems in the bootstrap that were due to the low proportion of telecommunications firms in our sample of firms with both Tekes evaluation grades. ***, **, *, and [a] denote significance at 1, 5, 10, and 15% level. Southern Finland is our base region.

A.5 Cross-validation

In the Table below, we present the cross-validation figures for the application and the investment equations. Cross-validation figures were calculated using equation (2.22) in Yatchew (1998).

Table A.5
Cross-validation of the Application and R&D Investment Equations

Specification	Application Equation	R&D Investment Equation
Linear term	0.0595	0.7961
+2nd power	0.0602	0.7982
+2nd and 3rd power	0.0586	0.8006
+2nd -4th power	0.0635	0.8039
+ 2nd and 3rd powers and 1st order interactions between continuous variables	0.0982	-

NOTES: the linear term is the effect of expected subsidies on expected discounted profits in the application equation, and the propensity score transformation that DNV use (Mills ratio) in the R&D investment equation. The base specification is the same as in the ML estimations.

III Eligibility, awareness and the application decision: An empirical study of firm participation in an R&D subsidy program

Abstract

This paper analyzes the application for research and development (R&D) subsidies in Finland. Finnish firm-level data on applicants and potential applicants is used to characterize firms application behavior. In addition to analyzing the characteristics underlying application for R&D subsidies, this paper also examines the use of count data models in modeling the application for R&D subsidies. The findings of this paper suggest that firms that are the most likely to have eligible projects, are also aware of the R&D subsidy program. The results also suggest that the opportunity cost of applying is lower for firms quite at the beginning of their life cycle, and provide evidence that external knowledge is important in lowering the application cost. Industry level heterogeneity in application behavior seems to be related to the application activity of potential applicants rather than the awareness of the program. The model selection exercise indicates that in using a count data framework to model the application behavior it is important to take into account both unobserved heterogeneity and excess zeros.

JEL classification: D21, O31, O38

Keywords: R&D, subsidies, application decision, eligibility, awareness, count data model

1 Introduction

Direct research and development (R&D) subsidies to business sector are a widely used policy tool to encourage industrial R&D. They are the second largest and fastest growing form of industrial aid in developed countries (Nezu, 1998). In Finland where the data of this paper originates, R&D subsidies are the most important tool of innovation policy (Georghiu et al., 2003). Given the importance of R&D subsidies we know surprisingly little about the processes that allocate them. There is a widespread political urge to get plausible evidence about the effectiveness of this policy tool in terms of additionality, productivity and growth, but it seems that this pronounced focus on impact estimates has diverted attention from the issue of allocation. To get reliable evidence of the effectiveness and functioning of a policy tool like R&D subsidies, the participation process determining who is finally granted a subsidy has to be well understood (Heckman and Smith, 2004). The participation process consists of two decisions: application decision and granting decision. In addition to asking who is selected into R&D subsidy programs and how, it should be asked who applies for R&D subsidies and why. The objective of this paper is to provide an explorative step toward understanding firms application behavior by analyzing the application for research and development subsidies in Finland.

Heckman and Smith (2004) provide three reasons why understanding the participation process is important:

1. Helps to identify the sources of inequalities in the receipt of government services.

2. Reveals information about the functioning of the program.

3. Provides information for more reliable econometric evaluation.

The first point stresses the need to have a thorough understanding of how different stages of the participation process shape the participation of different groups in a program. If there is unequal participation in a program it is important to know which stage of the process creates this inequality. For example is it the case that a specific group is less aware of a program than others, or is there unequal behavior at the application phase. The second point highlights that the participation process helps to understand how a program actually operates. Understanding the outcomes of choices made by potential participants on the one hand, and government bureaucrats on the other hand at different stages of the participation process helps identifying potential unexpected behavior not intended by the policy design.

The last point has to do with the selection bias related to microeconometric evaluation of different programs. There is a growing literature on quantitative evaluations of the effects of public R&D subsidies on private R&D activities, but results of the analyses are contradictory (see David, Hall, and Toole, 2000, and Klette, Møen and Griliches, 2000, for surveys). The confusing empirical findings have raised the question whether the econometric setups have been adequately specified (Klette, Møen and Griliches, 2000 and Jaffe, 2002). One of the major problems of these studies has been selection bias, which reflects the fact that outcomes of potential applicants who have not received a subsidy may differ systematically from what the outcomes of subsidized participants would have been in the absence of subsidies.[1] This selection bias makes it difficult to identify the effect of a public subsidy. An understanding of the participation process creating the selection problem provides basis for more reliable microeconometric evaluation studies.[2]

As mentioned above, the participation process consists of two decisions: an application decision by firms and a granting decision by the government. Potential participants decide whether to apply for a subsidy or not and the government bureaucrats administering R&D subsidies decide to which applicants to grant a subsidy. Often the latter is highlighted. The discussion about the allocation of R&D subsidies has centered on the question of whether the government can identify projects with high social returns that the private sector would not undertake on its own. Little attention is paid to the application behavior of firms.

In this paper I use Finnish firm-level data on applicants and potential applicants to characterize firms application behavior. To the best of my knowledge there are no previous studies focusing on the application phase of R&D subsidy programs. Blanes and Busom (2004) analyze the participation of firms in R&D subsidy programs, but their data does not allow distinguishing between the application and approval phases. Lichtenberg (1998) analyzes the determinants of allocation of public biomedical research expenditure. More specifically, he ana-

[1] Heckman, Ichimura, Smith and Todd (1998) provide an extensive treatment of the selection bias.

[2] There is a vast literature discussing the role of participation process in econometric evaluations of social programs. Heckman, LaLonde and Smith (1999) cover extensively issues related to econometric evaluation, and Heckman, Ichimura and Todd (1997, 1998) discusses participation process especially in relation to the method of matching.

lyzes how different characteristics of disease burden affect the amount of public research expenditure allocated on a disease. Feldman and Kelley (2001) in turn study how the attributes of a firm's R&D strategy affect the chances of winning an award from the Advanced Technology Program.

In addition to analyzing the characteristics underlying application for R&D subsidies, this paper also examines the use of count data models in modeling the application for R&D subsidies. The rich data at hand allows the identification of applicants and non-applicants, but it also contains information on the number of applications a firm has submitted during the observation period. This kind of data calls for a count data model. Given that there is little evidence on how to use count models in modeling application for R&D subsidies, it is not straightforward to decide what kind of a count data model should be used. As a result, various count models are estimated and compared.

The model selection exercise indicates that in using a count data framework to model the application behavior it is important to take into account both unobserved heterogeneity and excess zeros. Ignoring the issue that the sample consists of both non-applicants and potential applicants can distort the results. The interpretation of several regressors changes under the assumption that the sample is a mixture compared to an analysis conducted under the assumption that all the observations come from the same data generating process. Considering the sample as a mixture has also intuitive appeal. It provides a statistical method for assessing whether a firm belongs to the group of potential applicants.

The findings of this paper suggest that firms that are the most likely to have eligible projects, are also aware of the R&D subsidy program. In other words, the program seems to reach firms that are the most potential participants. In addition, the results indicate that the opportunity cost of applying is lower for firms quite at the beginning of their life cycle. The results also provide evidence that external knowledge is important in lowering the application cost. Industry level heterogeneity in application behavior seems to be related to the application activity of potential applicants rather than the awareness of the program.

The structure of this paper is the following. Section 2 overviews the business funding activities of the Finnish Funding Agency for Technology and Innovation. Section 3 discusses the application decision in relation to the whole participation process that determines who participates in R&D subsidy programs. Section 4 introduces count data models, discusses features of the sample in question and presents model selection process. Section 5 describes the data and Section 6 provides the results obtained from different count data models. Section 7 presents some conclusions.

2 Overview of business R&D funding activities of Tekes[3]

The Finnish Funding Agency for Technology and Innovation (Tekes) is the principal public promoter of private R&D in Finland and also the most important public financier of business R&D. The primary objective of Tekes is to promote the competitiveness of Finnish industry and the service sector by technological means. This is done by providing funding and expert services to both business and public R&D. Public R&D consists of research conducted in universities, academic institutions and research institutes. According to the Tekes annual report 2004, Tekes funding amounted to 409 million euros in 2004, of which 237 million euros was allocated to the business sector. In terms of projects this translates into 2242 projects of which 1464 were business R&D projects. In this paper the focus is on the business R&D funding activities of Tekes.

Business R&D funding is meant for firms operating in Finland and striving to improve business operations by technological means (www.tekes.fi). However, one clear trend in the business funding of Tekes has been the increasing role of small and medium sized firms (SMEs).[4] Large firms are not excluded from Tekes funding, but requirements imposed on them are somewhat more stringent compared to SMEs. Large firms' projects should fulfil at least one of the following criteria: networking with SMEs and universities or research institutes, participation in a technology program (technology programs are explained in the next subsection), participation in an international R&D project and network, a project consisting mainly of industrial research, or research outcomes have to become public. Both in terms of applications received and amounts granted the relative share of SMEs grew steadily especially over the 90s. The same trend has continued after the 2000, but to a lesser extent. The share of applications by firms with less than 100 employees increased from 36 percent in 1990 to 69 percent in 2000 and the share of business funding allocated to SMEs rose from

[3]This section relies on publicly available material that consists of Tekes annual report 2004, "World of technology, Joy of innovation" brochure of Tekes and information from website www.tekes.fi concerning the business funding of Tekes.

[4]An enterprise is considered a SME if 1) it has less than 250 employees, 2) large firms ownership is under 25 % and 3) its yearly turnover is less than 40 million euros or its balance sheet total is not over 27 million euros.

22 percent in 1990 to 53 percent in 2000. In 2004, SMEs received 55 percent of the total business R&D funding of Tekes.

2.1 Funding instruments

Key funding instruments of Tekes are grants and low-interest loans. In 2004, 70 percent of the business R&D funding consisted of grants. In general the same criteria apply to both grants and subsidized loans. However, distance to market is a key element determining the suitable funding instrument: grants are directed to R&D work done at the early phases of the innovation process that involve greater uncertainty, namely generation of new knowledge and prototypes that provide a basis for new marketable applications. Subsidized loans and capital loans are aimed at R&D work in the later stages of the innovation process in which the focus is on developing a complete marketable product or service. In practice the distinction between different phases of the innovation process is not clear-cut and a project can incorporate both stages. As a result, Tekes funding can be a combination of several instruments.

Almost half of Tekes business R&D funding is steered through technology programs. Technology programs aim at strengthening key technologies and expertise from the perspective of Finland's future. In addition technology programs aim at promoting collaboration, networking, and the diffusion of technologies.

2.2 Funding criteria

Tekes uses a selective funding practice that follows specific predefined criteria to allocate the funding. The qualification criteria used in the project evaluation are related to:

a) *the business activity to be pursued* - The goal is to promote projects that generate profitable business opportunities for global markets.

b) *the technology, innovation or competence to be developed* - The technology, innovation or competence to be developed should be technologically new and challenging at least to the company itself. In addition, knowledge and know-how created within the project should generate long lasting competitive advantage to the company.

c) *the resources reserved for the proposed project* - To be realistic the project proposal should incorporate adequate human and economic resources and the overall economic stance of the company should be in order.

d) *co-operation within the project* - One central aim of Tekes funding is to promote both domestic and international networking with other companies, universities and research centers.

e) *societal benefits of the project* - Societal benefits that favor Tekes funding are: positive environmental effects, balanced regional development, amelioration of the Finnish working and living conditions, improvements to back up the development of social welfare, healthcare and equality, and promotion of the national energy strategy.

f) *the effect of Tekes funding on the project* - The aim is that with Tekes funding the companies are willing to carry out more challenging R&D projects than they otherwise would and that by providing resources for efficient networking the funding enhances the widespread use of the benefits of the project in the Finnish economy.

Technical advisers evaluate each project proposal and compare it to other project proposals. Since the amount of funding is limited, it is not enough for a project proposal to fulfill the Tekes criteria in order to get funding, but it must also succeed in the competition against other proposals. The evaluation is done compared to the relevant domestic and international reference group. In addition to the project, also the company is evaluated.

3 Application as part of the participation process

Heckman and Smith (2004) decompose the participation process into five different stages: eligibility, awareness, application, acceptance and enrollment. Even though Heckman and Smith discuss participation in a social program such as a job training program, their framework can also be applied to R&D subsidies. The main scope of this paper is to analyze the application stage. In addition, eligibility and awareness will be discussed. The last two stages acceptance and enrollment are outside the scope of this paper and are not discussed further. The third essay examines the acceptance stage.

3.1 Eligibility for R&D subsidies

Eligibility determines the target group for the policy. In the case of R&D subsidies, eligibility has a somewhat different connotation compared to many social programs that often have explicit eligibility rules. R&D subsidies are allocated to specific innovation projects, so both the applicant (firm) and the innovation project have to be eligible for a subsidy. Often the project level eligibility is difficult to define in practice and determining eligible applicants is seldom a straightforward exercise.

In Finland the basic eligibility criteria for firms is that that the firm operates in Finland and strives to improve business operations by technological means (www.tekes.fi). This means that basically any firm operating in Finland can apply for R&D subsidies. Eligibility at the project level is far more complicated. There are no explicit eligibility rules for projects. The overall guideline is that in the long run, tax revenue from a project should outweigh the tax-paid public investment (www.tekes.fi). Publicly stated funding criteria basically determine eligibility, but they are very broad, abstract, numerous and rely on subjective evaluation (see previous section). This gives room for a variety of interpretations. Based on the official funding criteria, it is difficult to judge whether a project is eligible for Tekes funding or not.

Given that project level eligibility is hard to define in practice, it is difficult to construct a sample of eligible applicants based on both firm level and project level eligibility. As a result, it is common to construct samples based upon firm level eligibility. This is the case also in this study. The sample used in this paper consists of manufacturing firms and firms belonging to the knowledge intensive service sector operating in Finland.

3.2 Awareness of R&D subsidies

The difficulty in defining eligibility has implications for awareness. As Heckman and Smith (2004) argue, applicants have to be aware of the program and of their eligibility for it. A firm may be aware of R&D subsidies, but misinterprets eligibility. In the Finnish case I would argue that Tekes as such is well known in Finland. Tekes was established in 1983, so it has a well established position among the actors of Finnish technology policy. This is further supported by the role of Tekes as a centralized agency administering government R&D subsidies. In addition, Tekes has a strong regional representation through regional Employment and economic development centers (see www.te-keskus.fi). Tekes also has quite a good visibility in the Finnish media. In 2005, electronic media coverage of Tekes consisted of 2860 news.[5]

In terms of the funding Tekes provides the situation may be different. As noted above, the official funding criteria give room for a variety of interpretations and based on them, it is difficult to judge whether a project is eligible for Tekes funding or not. A potential applicant may be aware of Tekes, but incorrectly thinks that the project is not suitable for Tekes funding. This argument is supported by the fact that the majority of the applicants contact Tekes before submitting an application.[6] In fact, on their website, Tekes suggests potential applicants to contact Tekes to discuss the project idea before submitting an application (www.tekes.fi). Even though this kind of services provided by Tekes reduce the information barrier due to difficulties in determining whether a project is eligible for Tekes funding or not, they are unlikely to completely eliminate problems related to awareness.

3.3 The application decision

In the application stage potential applicants decide whether to submit an application or not. In making this decision, a firm weights expected benefits against the costs of applying. The main benefit to the firm from R&D subsidies is that they reduce the cost of R&D. In relation to technology programs, Tekes also highlights the benefits from networking and information sharing between companies and research communities (http://www.tekes.fi/English/programmes /what/what.html).

There are also costs associated with applying. It takes time and effort to gather the information required in the application process and to fill in the application form. Moreover the opportunity costs of the effort of making and promoting an application are probably far greater than the direct monetary costs of filling in and filing it. There are also additional administrative procedures associated with R&D subsidy programs: firms have to organize a separate bookkeeping for the subsidized project, approval of Tekes is needed if the content of the project changes once the project is launched, and firms have to report about the progress and outcomes of the project during, at the end and after

[5]Information obtained from Tekes in May 2006. Tekes uses News Now -service from M-Brain (www.m-brain.fi/English/newsnow.html) to get information about media coverage.

[6]This observation came up during the interviews and discussions I conducted while staying 11 months at Tekes in 2001.

the project.[7] In addition, publicity requirements, related especially to projects funded within technology programs, may prevent some firms from applying.[8]

The above discussion highlights that there are several reasons why a firm may not send an application. First, a firm simply is not aware of the program. Second, a firm may be aware of the program but misinterprets eligibility. Third, the activities of a firm may be outside the scope of the program. Fourth, application costs are so high that it is not profitable for a firm to apply.

4 The econometric setup

The data at hand does not only provide information on whether a firm submitted an application to Tekes, but also the number of applications submitted by a firm during the observation period is known. As a result I analyze the application for R&D subsidies by examining the number of applications a firm has submitted to Tekes during the observation period. This set up calls for a count data model. A standard candidate for a count data model would be the Poisson regression model (PRM) (see e.g. Greene, 1997 or Wooldridge, 2002). One characteristic of the PRM is that it assumes equidispersion. However, often the conditional variance exceeds the conditional mean, i.e. there is overdispersion. This overdispersion can be a consequence of unobserved heterogeneity, excess zeros, occurrence dependence between events or a combination of them. Especially in cross section data, it is difficult to identify the source of overdispersion.

4.1 Overdispersion due to unobserved heterogeneity

The solution to unobserved heterogeneity lies in more flexible modeling of the variance function.[9] This can be done in two ways: 1) moving away from the complete distributional specification to a specification of the first two moments, or 2) specifying a distribution that permits more flexible modeling of the variance than the Poisson. The first solution relies on the fact that the maximum likelihood (ML) estimator provides consistent estimates of PRM as long as the conditional mean function is correctly specified. The complete distributional assumption can thus be relaxed in favor of more general modeling of the variance function without loosing consistency of the estimates. This leads to what

[7] These problems related to administrative burden are not specific to Finland, but applies to R&D programs in general (Investing in Research and Innovation, 2004).

[8] Tekes publishes abstracts of projects funded within technology programs.

[9] Sections 4.1 and 4.2 rely on Cameron and Trivedi (1998).

Cameron and Trivedi (1998, 1986) call the Poisson pseudo maximum likelihood (PML) estimator. There are various standard error estimators depending on what functional form, if any, is assumed for the variance function.

One way to apply the second solution is to use continuous mixture models. In a continuous mixture model a stochastic error term is introduced into the conditional mean function reflecting the fact that the true mean is not fully observed. One common approach is to use a multiplicative stochastic error term. Various generalized count models can be generated by mixture models. One example is the widely used negative binomial model that can be represented as a Poisson-gamma mixture. The two common versions of the negative binomial model are what Cameron and Trivedi (1998) call the the NB2 and the NB1 models.[10]

4.2 Overdispersion due to excess zeros

In some cases, data display overdispersion through excess zeros. This means that the probability of obtaining a zero count is higher than what is consistent with the Poisson or some other specified distribution. The underlying reason for excess zeros is that zeros and the positives are generated by different data generating processes. Hurdle and zero-inflated models are the commonly used modified count models that deal with excess zeros.[11] These models alter both the conditional mean and the conditional variance functions relative to the PRM.

In the hurdle model the underlying idea is that a binomial probability model determines whether a zero or a positive realization is observed. If the hurdle is crossed, then a truncated-at-zero count model determines the conditional distribution of the positives. If y_i is the observed count for observation i, then the probability mass function is of the form

$$\Pr(y_i = j) = \begin{cases} f_1(0), & j = 0 \\ \frac{1-f_1(0)}{1-f_2(0)} f_2(j), & j > 1, 2, .. \end{cases} \quad (1)$$

Where $f_1(.)$ and $f_2(.)$ are the probability mass functions related to the binomial

[10] Let μ_i denote the expected count for observation i. NB2 model yields a variance function $\mu_i(1+\alpha\mu_i)$ and NB1 model a variance function $(1+\alpha)\mu_i$. Both versions imply overdispersion as long as α is greater than zero. If $\alpha = 0$ we are back at the PRM. Estimation of PML with variance function$(1+\alpha)\mu_i$ yields the ML estimates of the NB1 model.

[11] Hurdle model dates back to Cragg (1971) and Mullahy (1986), whereas Lambert (1992) and Greene (1994) have introduced the zero-inflated model.

probability model and the count model respectively. Various probability mass functions can be specified. In this study the binomial probability model is a logit model with parameter vector γ, and the truncated at zero count process is specified to follow either a Poisson or a negative binomial distribution, with parameters β related to covariate-vector $\boldsymbol{x}$.

In the zero-inflated count models it is in turn assumed that zeros can occur in two distinct states. There are two populations: one for which the event of interest is unlikely to occur and the other that experiences the event of interest according to a count data process. There are two data-generating processes at work: the first data-generating process determines whether an observation remains in a stage in which the event of interest does not occur or moves to a stage in which events occur at some rate. The second data-generating process generates the observed count that can also be zero.

Let q_i denote the probability that observation i stays at the state in which events do not occur. Correspondingly $(1 - q_i)$ denotes the probability that observation i moves to the state in which the observed count is generated. The zero-inflated count data model specification for the probability of observing a count j for observation i is

$$\Pr(y_i \quad = \quad j) = \begin{cases} q_i + (1 - q_i)f(j), & j = 0 \\ (1 - q_i)f(j), & j > 1, 2, .. \end{cases} \tag{2}$$

where $f(.)$ is the probability mass function of the chosen probability distribution related to the count data process, usually a Poisson or a negative binomial distribution, with parameters β related to covariate-vector $\boldsymbol{x}$.

q_i is allowed to be determined by a binomial probability model with a set of covariates $\mathbf{w}_i$. Let z denote a binary indicator variable that takes a value 1 if observation i stays at state one, and a value 0 if observation i moves to the second state. Then

$$q_i = \Pr(z_i = 1) = F(\mathbf{w}_i, \gamma). \tag{3}$$

$F(.)$ is the cumulative distribution function related to the chosen binomial probability model. Standard candidates for the distribution are the standard normal distribution (generating a probit model) and the logistic distribution (generating a logit model) with parameter vector γ reflecting the impact of changes in

$\mathbf{w}_i$ on the probability. In this study *F(.)* is the cumulative distribution function of a logistic distribution and *f(.)* is the probability mass function of either a Poisson or a negative binomial distribution.

4.3 Characteristics of the data and reflections on the application process

Returning to the current application, the data indicates there are signs of both overdispersion and excess zeros in the data. Table 1 below reveals that the variance is over six times larger than the mean, suggesting that overdispersion is left even once the effect of covariates is taken into account. Intuition suggests that unobserved heterogeneity may be present at least through occurrence dependence. Once a firm has applied for R&D subsidies, it is likely that filling the second application requires less effort. In other words, it is likely that previous applications increase the probability of subsequent applications. This would favor a negative binomial distribution over a Poisson distribution in modeling the occurrence of applications. In addition, Table 1 reveals that the data contain significantly more zeros than would be predicted by a Poisson distribution with a mean of 0.1497. This suggests the presence of excess zeros. Is it reasonable to suppose that excess zeros are the result of the underlying data generating process?

Table 1: *Summary statistics and the frequency distributions of the number of applications per firm.*

	Mean	Median	Std. Dev.	Min	Max
# applications per firm	0,1497	0	0,9693	0	66

Frequency	0	1	2	3	4+
Actual (# firms)	11242	709	189	67	68
Predicted by Poisson with mean 0,1497	10569	1582	118	6	0

There are two circumstances under which a firm does not send any applications during the observation period. First, a firm may send an application at some other time, or may have sent an application in the past, but during the observation period the firm does not submit any applications. This can happen for example because the firm does not launch any suitable new projects during the observation period or it does not see it profitable to send an application for the kind of projects launched during the period in question due to e.g. variation in opportunity costs. In the following, I call this kind of firms interim non-applicants. Second, a firm may never even consider submitting an application. This can happen because the firm is not aware of the program, or because the scope of the firms activities in general is not suitable for the program.[12] In other words, there are firms that do not consider submitting an application under any circumstances. These firms are called real non-applicants in the following. Potential applicants consist of both applicants and interim non-applicants.

The main underlying difference between the hurdle model and the zero-inflated model is that in the hurdle model only positives are allowed in the count data process part of the model, whereas the zero-inflated model allows some zeros to arise also from the count data process. This difference could be interpreted so that the hurdle model makes a distinction between those firms that apply, and those that do not apply. The zero-inflated model, in turn, separates between firms that are likely to apply and firms that do not consider applying. When considering the application process generating the observed count of applications, both setups could be plausible. If the data at hand consist of a well defined sample of potential applicants, i.e. applicants and interim non-applicants, then intuition supports the hurdle model. A zero observation is generated when a potential applicant decides not to send an application and the hurdle model separates between interim non-applicants and applicants. Alternatively, the data may consist of a more general sample of firms: applicants, interim non-applicants and also real non-applicants. In this case, intuition favors the zero-inflated model.

As explained in section 3.1, it is in general not straightforward to define the eligibility for R&D subsidies. This being the case also here, the data at hand consist of a relatively broadly defined sample of firms that is likely to cover both real and interim non-applicants - in addition to applicants. Therefore the intuition would favor the zero-inflated model over the hurdle model.

4.4 The modeling approach

Given that the true cause of overdispersion is difficult to identify, the modeling approach chosen here is to start from the standard Poisson model and then test

[12] Arundel and Hollanders (2005) report that 55 percent of Finnish firms do not innovate.

and evaluate more general models. First, models that treat unobserved heterogeneity as the cause of overdispersion and allow for more flexible modeling of the variance than the PRM are estimated and tested. More specifically, the Poisson PML estimator is used with different variance function specifications and then the negative binomial model is estimated. Second, models that consider overdispersion as a consequence of excess zeros generated by true underlying behavior, namely the hurdle Poisson and zero-inflated Poisson models, are estimated. These models alter the conditional mean function with respect to the PRM. Finally hurdle and zero-inflated versions of the negative binomial model (NB2) are estimated. These models allow for both sources of overdispersion - unobserved heterogeneity and true underlying behavior generating excess zeros. Estimations are based on the method of maximum likelihood and model comparison and testing will be based on information criteria, overdispersion tests, comparison of average predicted probabilities of counts with empirical relative frequencies and chi-square goodness of fit test.

5 Data

The firm data I use, covering originally 14 657 Finnish firms, come from Asiakastieto Ltd. Asiakastieto is a for-profit company collecting, standardizing, and selling firm specific quantitative information. The sample is drawn according to the following criteria: the most recent financial statement of the firm in the register is for either 2001 or 2000, the firm is a corporation, and the industrial classification of the firm belongs to the manufacturing, computer and related activities, research and development, architectural and engineering activities and related technical consultancy, technical testing and analysis. The data are based on firms' official profit sheet and balance sheet statements, plus other information disclosed by the firms to public registries like the industrial classification, geographical location, number of employees, whether a firm is an exporter or an importer, and information related to the ownership of the firm and the board composition. After cleaning the data of firms with missing values, we are left with 12 275 firms.

These 12 275 firms were matched with application data from Tekes that covers business sector applications Tekes received during the period January 1st 2000 to June 30th 2002. In total there were 2168 enterprises that applied for product development or industrial research funding from Tekes during the period. The matching was done using the business codes of firms. There were 31 firms in the Tekes application data for which no business code was available so they could not be matched with the Asiakastieto data. In total 1030 applicants were found in the Asiakastieto data. In addition, Tekes provided information on the number of applications the 12 275 firms had submitted to Tekes before January, 2000. There are 1232 firms that have submitted applications to Tekes before January, 2000, but not in the sample period.

There are three principal reasons why some 1000 Tekes applicants could not be identified in our sample of potential applicants: 1) the firm did not operate in the industries from which the sample was formed; 2) the firm was so small that it was not obliged by law to send its balance and profit sheets to the official registry[13]; and 3) the firm did not have an official financial statement either in 2001 or in 2000, because it was so recently established or had not yet been officially established. In addition 109 Tekes applicants drop when the original data with 14 657 firms is cleaned of firms with missing values.

5.1 Quality of the data

As explained in the previous section, all manufacturing firms and firms belonging to knowledge intensive business sectors are regarded as constituting the population of interest in this study. It is important to assess how well the data at hand describes the overall population of chosen industries in Finland and the population of Tekes applicants. This was done by comparing the distributions of firms in the Asiakastieto data to the overall distributions of Finnish firms in manufacturing and knowledge intensive business sectors, and by comparing all the Tekes applicants to those identified in the Asiakastieto data. The overall distribution of Finnish firms in the relevant industries is provided by Statistics Finland.

The comparisons according to the industry classification reveal that the available data constitute a relatively good representation of the actual populations, both in general and in terms of Tekes applicants. In other words, the distribution of firms belonging to the Asiakastieto data is well in line with the overall distribution of Finnish firms across industries, and likewise the distribution of Tekes applicants identified in the Asiakastieto data fits well to the industry distribution of all Tekes applicants. However, in terms of size, the quality could be better. Very small firms are clearly underrepresented among

[13]Asiakastieto claims to cover well also these smaller firms, but apparently not all of them.

firms in the Asiakastieto data as well as among Tekes applicants identified in the Asiakastieto data. Looking at the granted funding further highlights this issue. Applicants identified in the Asiakastieto data cover 70 percent of granted Tekes funding compared to their 53 percent share of applicants. Taking into account the increased emphasis of Tekes on SMEs, the under-representation of micro firms is certainly something that has to be kept in mind when interpreting results.

5.2 Determinants of application

Table 2 displays summary statistics of explanatory variables for the whole sample, and Table 3 conditions the statistics on the application decision.[14] As Table 2 shows, firms in the sample are heterogeneous. They are on average 12 years old with 36 employees. A very high proportion, 97 percent, are SMEs according to the official EU standard (see footnote 4). As explained in section 2, the funding criteria of Tekes favor SMEs. Sales per employee (SALES_EMPL), a measure of efficiency or a crude indication of value added, is 115 thousand euros, and some 22 per cent have exports (EXPORTS). We also have information on two corporate governance variables. In some 14 percent of potential applicants, the CEO is also the chairman of the board (CEO_CHAIR). Such an arrangement can, on the one hand, improve the information flow between the board and the executive but, on the other hand, weakens the board's independence. The board of an average potential applicant has four to five members (BOARD). A larger board is more likely to include members with outside knowledge that may be useful either in conducting R&D (choosing among competing projects, organizing management of current projects, monitoring), or in the application process itself. APPLICATIONS indicates the number of application a firm has submitted to Tekes before the year 2000. PARENT is an indicator variable getting a value one if the firm is a parent company. R&D_INV is the capitalized R&D investment in the balance sheet divided by firm's book value of total assets at the end of the year and R&D is an indicator variable taking value 1 if the firm has reported R&D investments in the balance sheet. I am well aware of the prob-

[14] Sales figures and the R&D investment figures used are for the year preceding the first application or the nearest available of the preceding years back to 1999. There were 12 firms that applied in 2000 with 1999 figures missing. However 10 of them applied also in 2001 and the remaining two in 2002 so the figures for 2000 were used for these firms. 10 691 firms have figures for 1999, 1528 have figures for 2000 and 56 firms figures for 2001. R&D investment is measured as the share of total assets in the balance sheet. Other variables represent the state at the time of retrieval of the data, mainly the year 2000.

lems related to the balance sheet measure of R&D investment. For many firms, especially SMEs, it is difficult to separate R&D expenses from other activities of the firm. In addition, even larger firms with more established R&D departments do not necessarily want to announce figures related to their R&D expenditures. Unfortunately it is the only available measure of R&D investment.

Table 2: Descriptive statistics for the whole sample.

	Mean	Median	Std. Dev.	Min	Max
AGE	12	9	12.33	0	104
# EMPLOYEES	36	5	248.61	1	13541
SALES_EMPL	115	79	311	-1.000	26100
BOARD	4.38	4	2.04	1	10
APPLICATIONS	0.6	0	4.67	0	287
R&D_INV	0.004	0	0.038	0	0.76
R&D	0.04	0	0.18	0	1
PARENT	0.11	0	0.32	0	1
EXPORTER	0.22	0	0.42	0	1
SME	0.97	1	0.16	0	1
CEO_CHAIR	0.14	0	0.35	0	1

NOTES: There are 12275 observations. Data sources: Asiakastieto Ltd. otherwise; for data on applications, Tekes.

From Table 3 we see that applicants are larger than non-applicants. The median number of employees for non-applicants is 5, for applicants 27. Also the sales per employee is somewhat larger for the applicants. Despite the problems related to the used R&D measures, applicants stand out as more engaged in R&D activities. However, only 13 percent of applicants have reported R&D investment in the balance sheet, which clearly indicates the flaws related to the balance sheet figure of R&D investment. The applicants also tend to have larger boards. Quite naturally, applicants have more previous applications on average than non-applicants. The difference in both means and medians is 4. Export orientation stands clearly out among the applicants. 57 percent of applicants have exports compared to 19 percent of non-applicants. In addition the share of parent companies is substantially higher among the applicants.

Table 3: Descriptive statistics for applicants and non-applicants

	Non-applicants (11244)			Applicants (1033)		
	Mean	Std. Dev	Median	Mean	Std. Dev	Median
AGE	12	12.07	9	13	14.85	9
# EMPLOYEES	22	118.28	5	193	745.43	27
SALES_EMPL	113	320	78	138	186	100
BOARD	4.20	1.90	4	6.31	2.44	6
APPLICATIONS	0.2	1.23	0	4.5	15.1	1
R&D_INV	0.003	0.03	0	0.02	0.09	0
R&D	0.03	0.16	0	0.13	0.34	0
PARENT	0.09	0.29	0	0.36	0.48	0
EXPORTER	0.19	0.39	0	0.57	0.5	1
SME	0.99	0.12	1	0.84	0.37	1
CEO_CHAIR	0.14	0.35	0	0.15	0.35	0

NOTES: There are 12275 observations. Data sources: Asiakastieto Ltd. otherwise; for data on applications, Tekes.

6 Estimation results

6.1 Model evaluation and selection

Comparison and testing of models is based on Akaike and Bayesian information criteria (AIC and BIC respectively), a chi-square goodness of fit test (GoF-test), the likelihood ratio test (LR-test) and the Vuong-test. When comparing the standard Poisson regression model (PRM) to the pseudo maximum likelihood (PML) estimates and to the negative binomial model (NB2), estimated standard errors and overdispersion coefficient are also analyzed (Table 4). Table 5 summarizes the results of model comparison and testing.[15] In Table 6 the average predicted probabilities of counts generated by each model are compared with the empirical relative frequencies.

[15] Tables 8 and 9 in Appendix 1 present the results of model comparison and testing in more detail, and Table 10 in Appendix 2 shows full estimation results.

Table 4: Estimation results of Poisson PML and negative binomial model.

Variable	Poisson ML and PML							NB2	
	Coefficient	ML standard errors		PML standard errors			I t I[RS]	Coefficient	I t I*
		MLH	MLOP	NB1	RS	Boot			
ONE	**-4.8674**	0.1771	0.1454	0.2095	0.2406	0.2584	20.69	**-5.0091**	20.15
AGE	**-0.0442**	0.0043	0.0032	0.0051	0.0065	0.0083	6.81	**-0.0421**	6.45
AGE^2	**0.0004**	0.0000	0.0000	0.0001	0.0001	0.0001	6.29	**0.0004**	4.73
LNEMPL	**0.6111**	0.0469	0.0372	0.0560	0.0681	0.0838	8.97	**0.7389**	10.04
LNEMPL^2	**-0.0453**	0.0056	0.0039	0.0069	0.0095	0.0121	4.76	**-0.0734**	6.13
SALES_EMPL	**0.0005**	0.0001	0.0001	0.0002	0.0003	0.0003	2.02	-0.0003	1.52
SALES_EMPL^2	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	1.98	0.0000	0.75
APPLICATIONS	**0.0504**	0.0023	0.0017	0.0028	0.0033	0.0123	15.52	**0.1285**	11.80
APPLICATIONS^2	**-0.0001**	0.0000	0.0000	0.0000	0.0000	0.0001	11.54	**-0.0004**	10.92
R&D_INV	**1.8859**	1.2937	1.1832	1.4724	1.5567	1.7700	1.21	1.1064	0.56
R&D_INV^2	-1.1389	2.0895	2.0083	2.3520	2.2790	3.2153	0.50	-0.4366	0.13
R&D	**0.4428**	0.1064	0.0894	0.1209	0.1336	0.1588	3.31	**0.6916**	4.26
SME	-0.1487	0.9890	0.7220	0.1201	0.1459	0.1687	1.02	-0.2389	1.28
PARENT	**0.3871**	0.0599	0.0443	0.0713	0.0850	0.0866	1.55	**0.3881**	4.67
EXPORTER	**0.8800**	0.0694	0.0567	0.0806	0.0877	0.0872	10.04	**0.9506**	10.41
BOARD	**0.1819**	0.0115	0.0085	0.0138	0.0176	0.0191	10.34	**0.1784**	11.56
CEO_CHAIR	-0.0360	0.0763	0.0631	0.0866	0.0947	0.0939	0.38	-0.0131	0.14
α								**1.3355**	11.23
regional dummies	YES							YES	
industry dummies	YES							YES	
Pseudo-R^2	0.42							0.26	

Note1: The variance specifications underlying different standard error estimates are the following, MLH $\omega=\mu$, Hessian estimate; MLOP $\omega=\mu$, BHHH/outer product estimate; NB1 $\omega=\phi\mu=(1+\alpha)\mu$ where $\alpha=0.5640$; RS, unspecified ω, robust sandwich estimate: Boot, unspecified ω, bootstrap estimate with 200 iterations.

Note2: Industry and regional dummies were also included in the estimations and several of them were statistically significant. Appendix 2 presents full estimation results.

Note3: Figures in bold indicate that the coefficient estimate is statistically significant at least at the 10 % significance level.

** Based on MLH standard error estimates. RS standard error estimates were also calculated, but they were in line with the MLH estimates.*

Comparison of the ML estimates of PRM to the PML estimates and to the NB2 model indicates that unobserved heterogeneity may be present. As Table 4 shows, ML based standard error estimates[16] are substantially lower than the Poisson PML estimates.[17] This is an indication of overdispersion and suggests

[16] Hessian (MLH) and outer product (MLOP) estimates.

[17] The NB1 estimates based on the NB1 variance function $(1+\alpha)\mu_i$, and robust sandwich (RS) and bootstrap (Boot) estimates based on an unspecified variance function.

that the ML standard errors should not be used. A comparison of the PRM and the NB2 model also conveys that PRM is not adequate for the data, because the overdispersion parameter α gets a highly significant value in the NB2 model as Table 4 reveals. Table 5 also shows that both the AIC and BIC favor the NB2 model over PRM. Moreover, the LR-test rejects the PRM over the NB2 model. However, the GoF-test based on actual and predicted frequencies rejects both the PRM and the NB2 model.

Table 5: Summary of model selection results

	PRM	NB2	ZIP	Hurdle-Poisson	ZINB	Hurdle-NegBin
AIC	VI	V	II	IV	I	III
BIC	VI	IV	II	V	I	III
GoF-test	rejected	rejected	rejected	rejected	not rejected	not rejected
LR-test	rejected vs. NB2 rejected vs. H-P	rejected vs. H-NB	rejected vs. ZINB	rejected vs. H-NB		
Vuong-test	rejected vs. ZIP	rejected vs. ZINB				

Estimation results of zero-inflated (ZIP) and hurdle-Poisson models suggest that overdispersion through excess zeros is also something that should be taken into account.[18] Table 5 shows that based on AIC and BIC the ZIP model is preferred over the PRM and the NB2 model. The hurdle-Poisson model is also preferred over PRM. However, the information criteria favor NB2 over the hurdle-Poisson. In addition the Vuong test rejects PRM in favor of ZIP, and the LR-test rejects PRM against the hurdle-Poisson model. However, based on the results it is difficult to conclude whether the zero-inflated or the hurdle specification should be used. AIC and BIC favor the zero-inflated specification, but in terms of actual and predicted frequencies shown in Table 6 it is difficult to discriminate between the two. The chi-square goodness-of-fit test rejects both specifications.

The above analyses provide evidence in favor of both unobserved heterogeneity and excess-zeros. Estimation results related to negative binomial versions of the zero-inflated (ZINB) and the hurdle (Hurdle-NegBin) specifications provide further evidence in this respect. Both the information criteria and goodness-of-fit test favor the negative binomial specifications over the Poisson specifications. In addition the LR-tests reject ZIP in favor of ZINB and hurdle-Poisson in favor of hurdle-NegBin. This suggests that unobserved heterogeneity is present. A

[18] A Logit model is used in the binomial part in both models and the count processes follow a Poisson distribution.

Table 6: Actual and predicted cell frequencies for different models.

Frequency	0	1	2	3	4	5	6	7+
Actual	11242	709	189	67	24	13	5	26
Poisson	11080	938	160	47	19	9	5	16
NegBin	11279	710	141	51	25	14	9	46
ZIP	11217	686	238	77	27	11	5	13
Hurdle-Poisson	11242	661	229	79	30	13	6	13
ZINB	11268	654	211	73	29	13	7	20
Hurdle-Negbin	11242	709	192	65	27	13	7	20

Vuong test of NB2 versus ZINB and a LR-test of NB2 versus Hurdle-NegBin in turn provide evidence that overdispersion through excess zeros is also present. Both ZINB and Hurdle-NegBin are chosen over NB2.

The results suggest that taking into account both unobserved heterogeneity and excess zeros could be an improvement. However, the choice between ZINB and Hurdle-NegBin is less clearcut. AIC and BIC favor the zero-inflated specification. Chi-square goodness-of-fit tests do not reject either of the models, but Hurdle-NegBin seems to provide a better fit to the data when comparing the actual and predicted cell frequencies presented in Table 6. Based on these model comparisons it is not straightforward to conclude whether the zero-inflated or the hurdle specification should be used. Given that intuition presented in section 4.3 supports the zero-inflated specification, ZINB is selected as the final model.

6.2 Estimation results

Before analyzing the estimation results of ZINB in detail, it is interesting to have a look at the estimated coefficients of the NB2 versus the ZINB specifications presented in Appendix 2. The results show how the explanatory power of regressors in the ZINB specification is divided between the two processes compared to the NB2 model. For example the regressor EXPORTER has a highly significant coefficient in the NB2 model, but the two part model indicate that EXPORTER determines whether an observation belongs to potential applicants or not rather than the number of events. The same happens with the indicator variable R&D. This suggests that in order to get a more solid interpretation of the results, it is important to take into account excess zeros.

Table 7 presents the full estimation results of the ZINB model including industry and regional dummies and also marginal effects for the regressors. Marginal effects are presented for both parts of the model; i.e. with respect the unconditional expected number of applications, and the probability of belonging to the group of potential applicants. Moreover the marginal effects with respect to the unconditional mean of applications are divided between the effect due to a change in the probability of belonging to the group of potential applicants and due to change in the count process. Calculated marginal effects represent average response over all observations.[19]

6.2.1 Binary process

Coefficient estimates for the binary process reported in Table 7 indicate whether a regressor has a positive or negative influence on the probability of being a potential applicant. Given that eligibility and awareness determine whether a firm is a potential applicant, interpretation of the estimation results reflects upon the effect the regressors might have on these two components. Size of the firm is positively related to the probability of being a potential applicant, i.e. the larger the firm the likelier it is that the firm is a potential applicant. This effect may be due to eligibility and awareness. Larger firms are likelier to conduct innovative activities that are eligible for R&D subsidies, but also larger firms are likelier to be better informed about the subsidy program.

The positive coefficient of sales per employee reflects the activities of innovative firms that on average generate higher sales per employee compared to non-innovative firms. As a result firms with higher sales per employee are likelier to launch projects that are eligible for R&D subsidies. The number of members in the board of the firm increases the probability of being a potential applicant. This may suggest that a larger board is likelier to provide the firm with knowledge that increases the likelihood of the firm to be aware of the R&D subsidy program.

[19]For continuous regressors AGE, SALES_EMPL, APPLIC, and BOARD, marginal effect gives the change in the expected value of the dependent variable due to a one-unit change in a regressor. In the case of the logarithmic regressor LNEMPL, marginal effect gives the change due to one-percent change in the number of employees. The marginal effects of R&D_INV are calculated in terms of R&D_INV*100, giving the change in the dependent variable due to one-percent change in the share. Both the value of the variable and it's square are taken into account in the calculations. For dummy variables (R&D, SME, PARENT, EXPORTER, CEO_CHAIR, industry dummies and regional dummies) the calculated effect is the difference between the expected value of the dependent variable when the dummy variable gets a value one and the expected value of the dependent variable when the dummy variable gets a value zero.

Table 7: Estimation results of the zero-inflated negative binomial model.

Variable	Count process	Binary process	Marginal effects*			
	Coefficient	Coefficient	unconditional expected no of applications**			probability of being a potential applicant
			total	count	binary	
ONE	**-1.7273**	**-4.8967**				
AGE	**-0.0375**	-0.0159	-0.0040	-0.0035	-0.0004	-0.0011
AGE^2	**0.0004**	-0				
LNEMPL	**0.2148**	**0.5421**	0.0210	0.0147	0.0064	0.0199
LNEMPL^2	-0.0139	-0.0578				
SALES_EMPL	**-0.0015**	**0.0024**	-0.0002	-0.0002	0.0001	0.0002
SALES_EMPL^2	**0.0000**	**0.0000**				
APPLICATIONS	**0.0549**	**2.9102**	0.0865	0.0072	0.0792	0.2069
APPLICATIONS^2	**-0.0002**	**-0.0100**				
R&D_INV	-2.0647	17.2572	0.0015	-0.3165	0.4664	0.0122
R&D_INV^2	3.6626	-24.2221				
BOARD	**0.1068**	**0.1530**	0.0215	0.0173	0.0042	0.0109
Dummy variables						
R&D	0.1004	**1.6663**	0.0815	0.0198	0.0617	0.1660
SME	-0.1783	0.4665	-0.0158	-0.0286	0.0128	0.0301
PARENT	**0.2700**	0.3329	0.0553	0.0449	0.0104	0.0252
EXPORTER	0.0457	**1.6703**	0.0642	0.0080	0.0562	0.1539
CEO_CHAIR	-0.0624	0.0714	-0.0080	-0.0099	0.0019	0.0051
Industry dummies						
FOOD	-0.2616	0.6485	-0.0222	-0.0396	0.0174	0.0520
PAPER	0.0135	-0.6556	-0.0142	0.0021	-0.0163	-0.0415
CHEMI	**0.5386**	-0.6031	0.0866	0.1067	-0.0200	-0.0380
RUBBER	**0.3578**	-0.7429	0.0435	0.0651	-0.0216	-0.0461
MACHINE	**0.2858**	0.4039	0.0669	0.0537	0.0133	0.0308
ELECTRIC	**0.6824**	0.4120	0.1736	0.1562	0.0173	0.0318
RADIOTV	**0.4322**	0.0455	0.0877	0.0861	0.0016	0.0033
OTHERMAN	**0.3618**	**-0.8757**	0.0402	0.0654	-0.0252	-0.0558
TELECOM	0.5436	-0.4484	0.0969	0.1123	-0.0153	-0.0291
DATAPRO	**0.6080**	**1.9025**	0.2287	0.1444	0.0843	0.1821
R_D	**0.7310**	-0.1104	0.1528	0.1570	-0.0042	-0.0077
Regional dummies						
REGION2	-0.0055	-0.2002	-0.0063	-0.0009	-0.0054	-0.0141
REGION3	0.0622	**0.8630**	0.0382	0.0111	0.0272	0.0715
REGION4	0.1537	0.4726	0.0424	0.0276	0.0147	0.0366
REGION56	**0.4491**	**-1.5054**	0.0413	0.0825	-0.0411	-0.0799
α	**0.3760**					

* For dummy variables the difference between value with dummy = 1 and value with dummy = 0 are reported instead of marginal effects, i.e. E(y|.,d=1)-E(y|.,d=0) averaged over all observations.

** The total marginal effects with respect to unconditional mean are divided between the effect due to change in pr(potential applicant) (binary) and the effect due to change in E(y|x, potential applicant) (count).

***Marginal effects of R&D% are calculated in terms of R&D%*100

Note: Figures in bold indicate that the coefficient estimate is statistically significant at least at the 10 % significance level.

The three most important factors affecting the probability of being a potential applicant are the number of previous applications, the R&D dummy variable and whether the firm has exports or not, all of which have a strong positive effect on the probability. Together these three factors capture firms that most evidently belong to the group of potential applicants. When looking at the marginal effects in the last column of Table 7, the magnitude of the effect these factors have on the probability stands out clearly. The pronounced effect of these factors suggests that the R&D subsidy program reaches the most evident potential applicants - i.e. R&D oriented firms operating in international markets. However, at the same time it raises the question of whether R&D subsidies are capable of encouraging established non R&D oriented firms to engage in R&D activities.

Across industries there are small differences in the probability of being a non-applicant. Firms belonging to other manufacturing industries have a lower probability of being a potential applicant, whereas firms belonging to the data-processing industry have a higher probability of belonging to potential applicants compared to the base category of metal and metal products industry. The marginal effect reveals that belonging to the data-processing industry increases the probability of being a potential applicant by 18 percent. This result may be due to the sample period in question that covers the years of the IT-boom.

6.2.2 Count process

Coefficient estimates of the count process in Table 7 indicate the effect of the regressors on the expected number of applications for potential applicants. Whether a potential applicant sends an application depends on the costs of applying vis a vis expected benefits. On average, younger firms tend to send more applications. This could indicate that younger firms, with less internal funding and possibly facing financing constraints, are more in need of R&D subsidies. In other words, the opportunity cost of applying is lower for smaller firms. Firm size, measured as the number of employees, is positively related to the number of application. This result seems rather obvious. Larger firms are likelier to have several R&D projects underway simultaneously. Sales per employee is negatively related to the expected number of applications. This may reflect that innovative firms quite at the beginning of their life cycle are more in need of R&D subsidies. Those firms are at the stage in which the main focus is in developing something that is expected to generate revenues and higher sales per employee in the future. Together with the age of the firm this suggests that the opportunity cost of applying is lower for firms quite at the beginning of their life cycle.

The number of previous applications is positively related to the number of applications sent in the sample period. This result is intuitive. Numerous previous applications indicate that the firm is actively engaged in R&D. Moreover there may be learning going on. Through numerous applications the firm may have learnt a great deal about how to fill in the application and what kind of activities Tekes favours.

The number of members in the board of the firm is positively related to the expected number of applications. This may suggest that a larger board is likelier to provide the firm with knowledge that lowers the application costs. In addition firms that are parent companies have on average higher expected number of application than other firms. This may reflect the tendency of concerns to establish centralized research-oriented R&D laboratories within parent companies. Another explanation might be that the parent company administers applications originating from various companies of the consolidated corporation. In terms of application costs this could be interpreted so that, given the experience of parent companies in filling applications, the application cost for them is lower.

Industry dummies indicate that compared to metal industry, belonging to almost any other industry increases the expected number of applications - only exceptions are the food -, paper - and telecommunications industry. At the regional level the only difference is the region 5, which stands for Northern Finland and Lapland. It is quite surprising to notice that firms in Northern Finland or Lapland are on average more active applicants than firms in Southern Finland. This result is driven by the fact that there are a couple of active applicants among the few applicants from Northern Finland.

Marginal effects with respect to the unconditional expected number of applications are divided between the effect due to change in the probability of being a potential applicant and the effect due to change in the expected number of applications conditional on being a potential applicant. Marginal effects indicate the magnitude of the effect the regressors have. The first observation is that in general, effects seem relatively small. However, one should bear in mind that 92 percent of the firms have zero applications in the sample period. As a result the average expected number of applications is only 0.1497. This means that although the marginal effects may seem small in absolute terms, the effect of regressors cannot be interpreted to be negligible.

Marginal effects reveal that two thirds of the effect that the size of the firm has on the expected number of applications is generated by the effect size has on the expected number of applications conditional on being a potential applicant. In other words, in relation to the unconditional expected number of applications, size is more important in determining the number of applications than the probability of being a potential applicant. The opposite is true for the number of previous applications. 80 percent of the effect previous applications has on the expected number of applications is generated by the change in the probability of being a potential applicant. The marginal effect with respect to the number of members in the board indicate that the change in the expected number of applications is mainly generated by the effect BOARD has on the conditional count process. 80 percent of the total marginal effect is generated through the change in the conditional expected number of applications. Marginal effects with respect to the industry dummies further strengthen the observation that in general, industry level differences in the expected number of applications are mainly generated by different application activity of the potential applicants in different industries.

7 Conclusions

This paper examined the application for R&D subsidies using count data models. Given the importance of R&D subsidy programs as one of the main innovation policy tools, we know surprisingly little about the process that allocates them - i.e. the participation process. Heckman and Smith (2004) define the participation in a program as consisting of five different stages: awareness, eligibility, application, acceptance and enrollment. There are two important decision problems underlying this participation process: application decision of firms and acceptance decision of government bureaucrats. By focusing on the application stage, this paper provides an explorative step toward understanding firms' application behavior, which, to the best of my knowledge, has not been investigated before.

Applications for R&D subsidies are investigated by analyzing the number of applications a firm sent to the Finnish Funding Agency for Technology and Innovation (Tekes) during the period of January, 2000 - June, 2002. Tekes is the principal public promoter of private R&D in Finland and also the most important public financier of business R&D. I analyzed various count data models and found that it is important to take into account both unobserved heterogeneity and excess zeros when modeling the number of applications.

The zero-inflated negative binomial model provided an intuitive framework for the analysis and was chosen as the final model. The zero-inflated specification models the probability of being a potential applicant and the expected number of applications conditional on being a potential applicant. Estimation results indicated that omitting especially the problem of excess zeros may distort the results. The explanatory power of regressors in the zero-inflated specification is divided between the two processes compared to the corresponding non zero-inflated count model.

Estimation results yield several findings:

- The number of previous applications, reported R&D-investments prior to the sample period and export activities have a pronounced positive effect on the probability of being a potential applicant. This indicates that the R&D subsidy program seems to reach the most evident potential applicants - firms engaged in R&D activities and operating in international markets.

- Age of the firm and sales per employee have a negative effect on the application activity suggesting that the opportunity cost of applying is lower for younger firms with lower sales per employee.

- The number of members in the board of the firm is positively related to the number of applications. This suggests that external knowledge is valuable in lowering the application costs.

- Industry level heterogeneity is related to application activity of potential applicants rather than to the probability of being a potential applicant.

In terms of eligibility and awareness, the results of the binary process modeling the probability of being a potential applicant could be interpreted so that those firms that are the most likely to have eligible projects, are also aware of the R&D subsidy program. In other words, the program seems to reach firms that are the most potential participants, and in that sense the program could be considered to work well. However, if the aim of the program is also to encourage established firms to engage in R&D activities, the conclusion is less clear cut. The way firms engaged in R&D activities and operating in international markets stand out suggests that there may be problems related to the awareness of firms that are not "by definition" among the potential applicants.

In relation to the application decision, the results suggest that firms quite at the beginning of the life cycle are more in need of R&D subsidies and therefore have stronger incentives to apply. This result supports the policy argument related to R&D subsidy programs that due to market failures especially young innovative firms need public R&D support. In addition, this result suggests that an important target group of the policy finds the program attractive.

The finding that supports the usefulness of external knowledge in lowering application costs indicates that trying the reduce the applications costs firms face, could be important in increasing application activity. Industry level conclusions are that there does not seem to be considerable differences in the awareness of the program across industries, but the application behavior is somewhat heterogeneous. This may be due to both different industry characteristics and policy emphasis that favor specific industries over others.

References

[1] Arundel, Anthony and Hugo Holanders (2005): Innovation Strengths and Weaknesses, 2005 European Scoreboard on Innovation Paper.

[2] Blanes, Vicente J. and Isabel, Busom (2004): Who participates in R&D subsidy programs? The case of Spanish manufacturing firms, *Research Policy*, 33, 1459-1476.

[3] Cameron and Trivedi (1998): Regression Analysis of Count Data, Cambridge University Press.

[4] Cameron and Trivedi (1986): Econometric Models Based on Count Data: Comparison and Applications of Some Estimators, *Journal of Applied Econometrics,* 1, 29-53.

[5] Cragg, J. G. (1971): Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods, *Econometrica*, 39, 829-844.

[6] David, Hall and Toole (2000): Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, *Research Policy*, 29, 497-529.

[7] Feldman, M. P. and M. R. Kelley (2001): Winning an award from the advanced technology program: pursuing R&D strategies in the public interest and benefiting from a Halo effect, NISTIR 6577, US Department of Commerce.

[8] Georghiou, Luke, Keith Smith, Otto Toivanen and Pekka Ylä-Anttila (2003): Evaluation of the Finnish Innovation Support System, Ministry of Trade and Industry Publications, 5/2003.

[9] Greene, W. (1994): Accounting for Excess Zeros and Sample Selection in Poisson and Negative Binomial Regression Models, Working Paper No. EC-94-10, Department of Economics, Stern School of Business, New York University.

[10] Greene, William H. (1998): Econometric Analysis, third edition, Prentice-Hall Inc., US.

[11] Heckman, James (1992): Randomization and Social Program Evaluation, , in Manski, Charles and Irwin Garfinkel (eds.), Evaluating Welfare and Training Programs, Cambridge, Mass: Harvard University Press, 231-252.

[12] Heckman, James J., Hidehiko Ichimura, Jeffrey Smith and Petra Todd (1998): Characterizing Selection Bias Using Experimental Data, *Econometrica*, 66, 1017-1098.

[13] Heckman, James J., Hidehiko Ichimura and Petra Todd (1997): Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme, *Review of Economic Studies*, 64, 605-654.

[14] - (1998): Matching as an Econometric Evaluation Estimator, *Review of Economic Studies*, 65, 261-294.

[15] Heckman James J., Robert, J. LaLond and Jeffrey A. Smith (1999): The Economics and Econometrics of Active Labor Market Programs, in Handbook of Labor Economics, Volume 3A, 1865-2097, Amsterdam: North-Holland.

[16] Heckman, James J. and Jeffrey A. Smith (1995): Assessing the case for Social Experiments, *The Journal of Economic Perspectives*, 9, 85-110.

[17] Heckman, James J. and Jeffrey A. Smith (2004): The Determinants of Participation in a Social Program: Evidence from a Prototypical Job Training Program, *Journal of Labor Economics*, 22, 243-298.

[18] Investing in Research and Innovation: Realising the Potential of Public - Private Interaction, Report summarising the results of the conference, held in Noordwijk, the Netherlands, October 12 and 13 2004, as part of the Dutch EU Presidency.

[19] Jaffe , Adam B. (2002): Building Programme Evaluation into the Design of Public Research-Support Programmes, *Oxford Review of Economic Policy*, 18, 1, 22-34.

[20] Klette, Moen and Griliches (2000): Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies, *Research Policy*, 29, 471-495.

[21] Lambert , D. (1992): Zero-Inflated Poisson Regression with an Application to Defects in Manufacturing, *Technometrics*, 34, 1-14.

[22] Lichtenberg, Frank R. (1998): The Allocation of Publicly-Funded Biomedical Research, NBER Working Paper 6601.

[23] Moffit, Robert (1992): Evaluation Methods for Program Entry Effects, in Manski, Charles and Irwin Garfinkel (eds.), Evaluating Welfare and Training Programs, Cambridge, Mass: Harvard University Press, 231-252.

[24] Mullahy, J. (1986): Specification and Testing of Some Modified Count Data Models, *Journal of Econometrics*, 33, 341-365.

[25] Nezu, Risaburo (1998): Trends and Patterns of Public Support to Industry in the OECD Area, STI Review, 21, 12-24.

Appendix 1

Table 8: Model selection criteria for the estimated count data models.

	PRM	NB2	ZIP	Hurdle-Poisson	ZINB	Hurdle-NegBin
-lnL	3742	3510	3209	3379	3161	3341
AIC	7516	7052	6450	6822	6354	6747
BIC	7785	7322	6719	7361	6623	7294
T_{GoF}	81	32	13	27	12	3
α*		0.336 (11.23)			0.376 (6.39)	0.719 (3.24)

* t-value in parenthesis

** Goodness-of-fit test statistic. $\chi^2(7)$ critical value at the 5 percent level is 12.02.

Table 9: Tests of different models.

LR-test			Vuong-test		
PRM vs. NB2	T_{LR} = 464 df=1	PRM rejected	PRM vs. ZIP	T_V = 12.6	PRM rejected
PRM vs. H-P	T_{LR} = 724 df=32	PRM rejected	NB2 vs. ZINB	T_V = 12.3	NB2 rejected
NB2 vs. H-NB	T_{LR} = 338 df=32	NB2 rejected			
ZIP vs. ZINB	T_{LR} = 96 df=1	ZIP rejected			
H-P vs. H-NB	T_{LR} = 76 df=1	H-P rejected			

Appendix 2

Table 10: Estimation results

	Poisson PMLE		NB2		ZIP				Hurdle-Poisson			
					count process		binary process*		positives		zeros**	
Variable	Coefficient	$\lvert t \rvert^{RS}$	Coefficient	$\lvert t \rvert$	Coefficient	$\lvert t \rvert$	Coefficient	$\lvert t \rvert$	Coefficient	$\lvert t \rvert$	Coefficient	$\lvert t \rvert$
ONE	**-4.8674**	20.69	**-5.0091**	20.15	**-1.5394**	6.17	**-4.4389**	6.70	-1.8013	5.64	**-5.1050**	16.85
AGE	**-0.0442**	6.81	**-0.0421**	6.45	**-0.0378**	7.62	-0.0174	1.17	**-0.0367**	5.74	**-0.0475**	5.91
AGE^2	**0.0004**	6.29	**0.0004**	4.73	**0.0004**	6.99	0.0001	0.33	**0.0003**	5.07	**0.0004**	4.19
LNEMPL	**0.6111**	8.97	**0.7389**	10.04	**0.1156**	1.90	**0.6282**	3.76	**0.2036**	2.6	**0.7037**	7.41
LNEMPL^2	**-0.0453**	4.76	**-0.0734**	6.13	0.0028	0.41	**-0.0830**	2.69	-0.0011	0.13	**-0.0787**	4.81
*SALES_EMPL****	**0.0519**	2.02	-0.0365	1.52	**-0.1690**	5.33	**0.2500**	2.67	**-0.1880**	4.66	-0.0211	0.67
SALES_EMPL^2	**0.0002**	1.98	0.0001	0.75	**0.0057**	3.94	**0.0078**	2.66	**0.0067**	3.2	0.0000	0.01
APPLICATIONS	**0.0504**	15.52	**0.1285**	11.80	**0.0363**	14.33	**2.1933**	10.12	**0.0325**	10.61	**0.3376**	14.75
APPLICATIONS^2	**-0.0001**	11.54	**-0.0004**	10.92	**-0.0001**	9.09	**-0.0075**	5.24	**-0.0001**	6.55	**-0.0012**	13.09
R&D_INV	**1.8859**	1.21	1.1064	0.56	-1.7848	1.09	4.7436	0.45	-1.5002	0.72	0.5355	0.23
R&D_INV^2	-1.1389	0.50	-0.4366	0.13	3.3175	1.34	-6.7845	0.44	2.0005	0.62	2.2089	0.56
R&D	**0.4428**	3.31	**0.6916**	4.26	0.0285	0.21	**1.6714**	2.64	0.0940	0.53	**0.7669**	4.01
SME	-0.1487	1.02	-0.2389	1.28	-0.0432	0.38	-0.0226	0.04	-0.0315	0.25	-0.2147	0.86
PARENT	**0.3871**	1.55	**0.3881**	4.67	**0.2595**	3.75	0.2545	1.21	**0.1999**	2.28	**0.4829**	4.80
EXPORTER	**0.8800**	10.04	**0.9506**	10.41	0.0382	0.41	**1.4999**	6.84	0.1041	0.85	**1.0843**	10.28
BOARD	**0.1819**	10.34	**0.1784**	11.56	**0.1049**	7.74	**0.1436**	4.03	**0.1038**	5.91	**0.1840**	9.63
CEO_CHAIR	-0.0360	0.38	-0.0131	0.14	-0.0828	0.87	0.1168	0.53	-0.2095	1.57	0.0760	0.70
Industry dummies												
FOOD	-0.0058	0.03	-0.0113	0.05	-0.1907	0.82	0.4034	0.76	-0.3328	0.88	-0.0122	0.05
PAPER	0.0306	0.17	-0.1585	0.85	0.1542	0.86	**-0.8587**	1.96	0.1121	0.47	-0.2034	0.99
CHEMI	**0.5432**	2.34	**0.5559**	2.37	**0.5690**	3.78	-0.4931	0.86	**0.7864**	4.25	0.1918	0.64
RUBBER	**0.4927**	2.69	**0.3354**	1.92	**0.4644**	2.78	**-0.9245**	2.13	**0.6130**	2.71	0.1109	0.55
MACHINE	**0.6350**	3.81	**0.4701**	3.13	**0.4045**	3.03	0.1474	0.44	**0.5050**	2.75	**0.4094**	2.45
ELECTRIC	**1.0969**	6.46	**0.9664**	5.88	**0.7388**	5.37	0.2346	0.60	**0.8212**	4.4	**0.8703**	4.52
RADIOTV	**0.8125**	3.85	**0.7332**	3.29	**0.4195**	2.47	0.1706	0.28	0.4602	2.02	**0.5169**	1.88
OTHERMAN	0.0217	0.13	-0.0498	0.33	**0.4140**	2.79	**-0.8412**	2.63	**0.4594**	2.28	-0.1921	1.13
TELECOM	0.3488	1.11	0.1747	0.55	**0.5963**	2.21	-0.5336	0.86	**0.6643**	2.37	-0.2210	0.51
DATAPRO	**1.5997**	10.39	**1.7015**	11.60	**0.6170**	4.21	**1.6238**	5.09	**0.8338**	4.16	**1.6236**	9.86
R_D	**1.1863**	7.34	**0.9805**	6.64	**0.8220**	5.86	-0.2598	0.82	**1.1165**	5.86	**-0.6538**	3.84
Regional dummies												
REGION2	-0.0633	0.80	-0.0103	0.13	-0.0395	0.56	-0.1389	0.78	-0.1144	1.23	0.0293	0.32
REGION3	**0.3797**	3.38	**0.5206**	4.41	0.0079	0.11	**0.8449**	3.01	-0.2130	1.24	**0.6556**	4.87
REGION4	**0.2553**	1.87	**0.3250**	2.53	0.1501	1.15	0.4108	1.38	0.0570	0.39	**0.3996**	2.58
REGION56	0.2452	0.78	0.0800	0.37	**0.4785**	2.29	**-1.1701**	2.12	0.2614	1.09	0.0903	0.34
α			**0.3355**	2.82								
Pseudo-R^2	0.42		0.26		0.39				0.43		0.32	
-lnL	3742		3510		3209				3379			
AIC	7516		7052		6450				6822			
BIC	7785		7322		6719				7361			
T_{GoF}(df=7)	81		32		12.55				27			

** Pr(potential applicant)*
*** Pr(at least one application)*
**** In 100 000 euros*
Note: Figures in bold indicate that the coefficient estimate is statistically significant at least at the 10 % significance level.

Table 11: Estimation results (continued)

	ZINB				Hurdle-NegBin			
	count process		binary process*		positives		zeros**	
Variable	Coefficient	|t|	Coefficient	|t|	Coefficient	|t|	Coefficient	|t|
ONE	**-1.7273**	6.13	**-4.8967**	6.20	**-2.4359**	5.15	**-5.1050**	16.85
AGE	**-0.0375**	5.75	-0.0159	0.91	**-0.0375**	3.63	**-0.0475**	5.91
AGE^2	**0.0004**	4.91	0.0000	0.00	**0.0004**	3.03	**0.0004**	4.19
LNEMPL	**0.2148**	2.82	**0.5421**	2.81	**0.2940**	2.42	**0.7037**	7.41
LNEMPL^2	-0.0139	1.35	-0.0578	1.57	-0.0104	0.66	**-0.0787**	4.81
*SALES_EMPL****	**-0.0015**	3.58	**0.0024**	2.23	**-0.0021**	3.18	-0.0002	0.67
SALES_EMPL^2	**0.0000**	2.74	**0.0000**	2.38	**0.0000**	2.24	0.0000	0.01
APPLICATIONS	**0.0549**	9.80	**2.9102**	8.27	**0.0567**	6.56	**0.3376**	14.75
APPLICATIONS^2	**-0.0002**	7.60	**-0.0100**	2.83	**-0.0002**	5.15	**-0.0012**	13.09
R&D_INV	-2.0647	1.27	17.2572	1.05	-0.7750	0.27	0.5355	0.23
R&D_INV^2	3.6626	1.41	-24.2221	1.05	0.2022	0.04	2.2089	0.56
R&D	0.1004	0.70	**1.6663**	2.18	0.0767	0.31	**0.7669**	4.01
SME	-0.1783	1.14	0.4665	0.68	-0.0565	0.24	-0.2147	0.86
PARENT	**0.2700**	3.33	0.3329	1.32	0.1964	1.53	**0.4829**	4.80
EXPORTER	0.0457	0.45	**1.6703**	6.64	-0.0435	0.26	**1.0843**	10.28
BOARD	**0.1068**	6.85	**0.1530**	3.71	**0.1072**	4.38	**0.1840**	9.63
CEO_CHAIR	-0.0624	0.60	0.0714	0.29	-0.2012	1.16	0.0760	0.70
Industry dummies								
FOOD	-0.2616	1.05	0.6485	1.14	-0.3369	0.70	-0.0122	0.05
PAPER	0.0135	0.06	-0.6556	1.28	-0.0554	0.15	-0.2034	0.99
CHEMI	**0.5386**	2.45	-0.6031	0.88	**0.9655**	2.71	0.1918	0.64
RUBBER	**0.3578**	1.88	-0.7429	1.51	0.6142	1.87	0.1109	0.55
MACHINE	**0.2858**	1.81	0.4039	1.06	0.3944	1.37	**0.4094**	2.45
ELECTRIC	**0.6824**	4.15	0.4120	0.92	**0.8769**	3.05	**0.8703**	4.52
RADIOTV	**0.4322**	2.10	0.0455	0.06	0.5962	1.69	**0.5169**	1.88
OTHERMAN	**0.3618**	2.04	**-0.8757**	2.39	0.4356	1.42	-0.1921	1.13
TELECOM	0.5436	1.47	-0.4484	0.65	0.9663	1.84	-0.2210	0.51
DATAPRO	**0.6080**	3.61	**1.9025**	5.14	**0.8866**	3.00	**1.6236**	9.86
R_D	**0.7310**	4.40	-0.1104	0.31	**1.1152**	3.82	**-0.6538**	3.84
Regional dummies								
REGION2	-0.0055	0.07	-0.2002	1.00	-0.1126	0.85	0.0293	0.32
REGION3	0.0622	0.50	**0.8630**	2.62	-0.1665	0.77	**0.6556**	4.87
REGION4	0.1537	1.18	0.4726	1.44	0.1268	0.63	**0.3996**	2.58
REGION56	**0.4491**	1.81	**-1.5054**	2.24	0.2256	0.62	0.0903	0.34
α	**0.3760**	6.39			**0.7192**	3.24		
Pseudo-R^2	0.33				0.19		0.32	
-lnL	3161				3341			
AIC	6354				6747			
BIC	6623				7294			
T_{GoF}(df=7)	12.29				2.8			

** Pr(potential applicant)*

*** Pr(at least one application)*

**** In 100 000 euros*

Note: Figures in bold indicate that the coefficient estimate is statistically significant at least at the 10 % significance level.

IV Who is granted an R&D subsidy: Allocation of business R&D subsidies in Finland

Abstract

Research and development (R&D) subsidies to business sector constitute a selective policy tool to encourage private R&D activities. The efficiency and functioning of this tool depends on how the public agency allocates subsidies. This paper examines the allocation rule of the public agency. The program under scrutiny is that of the Finnish Funding Agency for Technology and Innovation (Tekes) for which I have data on everyone who applied over a two and a half year period. The results indicate that in general Tekes adheres to the stated funding policy and criteria. The technological content of the project proposal and risks related to the implementation of the projects are important in determining whether an application is accepted and the subsidy-level. In addition being a small and medium size company increases the acceptance probability. Also the extent of collaboration matters. All these findings are in line with the stated funding policy and criteria. However, Tekes seems to be avert to risks related to the commercial potential of the project proposal. It can be questioned whether this observation is in line with the stated objectives.

JEL classification: D02, D73, H20, O38

Keywords: R&D, subsidies, allocation, bureaucratic decision-making

1 Introduction

This paper examines the allocation of business research and development (R&D) subsidies by analyzing the determinants of acceptance into an R&D subsidy program. The program under scrutiny is that of the Finnish Funding Agency for Technology and Innovation (Tekes) for which I have data on everyone who applied over a two and a half year period. In order to assess the functioning and efficiency of R&D subsidy programs in practice, it is crucial to understand the overall allocation of subsidies - who is it that finally participates in the program and why. Given that R&D subsidies constitute a selective innovation policy tool, a central issue in the overall allocation is how the government allocates subsidies to applicants. Through consistent analysis of the rationals, design and functioning of an R&D subsidy program this paper provides a descriptive account of an R&D subsidy program, but also hopes to provide a more general discussion that is helpful in understanding the operations of R&D subsidy programs and identifying issues that should be carefully scrutinized. The focus in this paper is to analyze what matters in the actual allocation decisions of Tekes, whether this is consistent with the publicly stated policy and with the theoretical rationales justifying R&D subsidy policies and finally, whether the decision-making is consistent across different decision-making levels.

There are several reasons why Finland provides an interesting case to analyze how a key innovation policy instrument, direct R&D subsidies, is designed and implemented. First of all, Finland has experienced a particularly rapid and successful transformation to a successful technology intensive economy (Oinas, 2005 and Trajtenberg, 2001). Although Finland industrialized relatively late it has gained a leading positions in several recent international comparisons of technological advancement and economic competitiveness. Innovation policy has played a central role in government policy during the transformation and is often praised for contributing to the success of the Finnish economy (Hautamäki, 2001 and Schienstock and Hämälainen, 2001).

Second, direct R&D subsidies constitute a key ingredient of the Finnish innovation policy (Georghiu et al., 2003). Instead of being marginal and fragmented activity, R&D subsidies are at the core of the Finnish innovation policy. The program has been consistently operated and developed over the past twenty years. And third, unlike many other countries, the majority of R&D subsidies are administered by a single public agency, Tekes. Instead of several small, relatively focused programs administered by different institutions and adhering to different criteria, Finland has a relatively unified R&D subsidy program open in practice to all innovative firms operating in Finland. Given the perceived success of the Finnish innovation policy and the role of R&D subsidies as a key policy instrument it is worth analysing the Finnish R&D subsidy program.

The framework of the analysis in this study has relevance also in terms of quantitative program evaluation. In order to properly analyze the effects of public R&D subsidies on private R&D activities, the participation process creating the selection has to be well understood (see Heckman and Smith, 2004). The allocation rule of government bureaucrats constitute a central element of the participation process. Although the allocation rule is different for different R&D subsidy programs and the empirical results in this study are specific to the R&D subsidy program in question, this paper helps to structure our understanding of how the selection is actually created.

So far, little systematic attention has been paid to the allocation rule that government bureaucrats use to allocate R&D subsidies. One reason has certainly been the lack of data. Government agencies allocating R&D subsidies are not eager to give access to their databases - if they keep one. However, it also seems that the widespread political urge to get plausible evidence about the effectiveness of R&D policies in terms of additionality, productivity and growth has diverted attention from the issue of allocation. Yet, reliable impact estimates are difficult to get without a thorough understanding of the participation process that determines the allocation of R&D subsidies. In addition it is difficult to interpret the impact estimates and draw policy conclusions if the functioning of the policy instrument is not fully understood.

There are few papers that touch upon the issue of government allocation of R&D subsidies. Blanes and Busom (2004) analyze the participation of firms in R&D subsidy programs, but their data does not allow distinguishing between the application and approval phases. Lichtenberg (1998) analyzes the determinants of allocation of public biomedical research expenditure. More specifically, he analyzes how different characteristics of disease burden affect the amount of public research expenditure allocated on a disease. Feldman and Kelley (2001) in turn study how the attributes of a firm's R&D strategy affect the chances of winning an award from the Advanced Technology Program. This study has links also to the literature of bureaucratic decision-making that analyzes the preferences of government bureaucrats in various settings (McFadden, 1975; Mc Fadden, 1976; Thomas, 1988; Heckman et al., 1996 and Heckman et al., 1997).

The results of this study indicate that by and large the decision-making of

Tekes is in line with the publicly stated objectives and funding principles. The three key themes of the Tekes R&D subsidy program - technological risk, collaboration and small and medium size enterprises - clearly stand out in the actual decisions. The effect of these factors is especially pronounced on the probability of an application to be accepted. There is however, one aspect of the stated objectives that does not show up in the actual allocation accordingly. Risk related to the market outcome of the project has negative, if any, effect on the decisions. This may be somewhat in contradiction with the stated objectives of supporting the development of "global success stories" and "sharing the commercial risk related to the project". Decision-making across different decision-making levels seems to be relatively consistent. There is some variation in how some applicant characteristics affect the decisions at various levels, but it is not straightforward to determine whether the differences are due to diverging preferences or due to different firm-samples underlying each decision-making level.

The structure of the paper is the following. Section 2 shortly reviews the history and funding activities of Tekes. Section 3 discusses the theoretical issues related to R&D subsidies. Namely, the rationales for R&D subsidies and problems related to the design and implementation of R&D subsidy policies. Section 4 describes the design and implementation of the Tekes R&D subsidy program. Section 5 moves toward the empirical analysis by presenting the econometric setup and the underlying theoretical model. Section 6 describes the data and section 7 presents the estimation results. Finally, section 8 offers some concluding remarks.

2 Institutional background[1]

Tekes is the principal public promoter of private R&D in Finland and also the most important public financier of business R&D (for an overview of the Finnish innovation support institutions see e.g. Georghiu et al., 2003). Tekes provides funding and expert services to both business and public R&D. Public R&D consists of research conducted in universities, academic institutions and research institutes. According to the Tekes annual report 2004, Tekes funding amounted to 409 million euros in 2004, of which 237 million euros was allocated to the business sector. In terms of projects this translates into 2242 projects of

[1] This section relies on publicly available material that consists of Tekes annual report 2004, World of technology Joy of innovation brochure of Tekes and information from web-site www.tekes.fi concerning the business funding of Tekes.

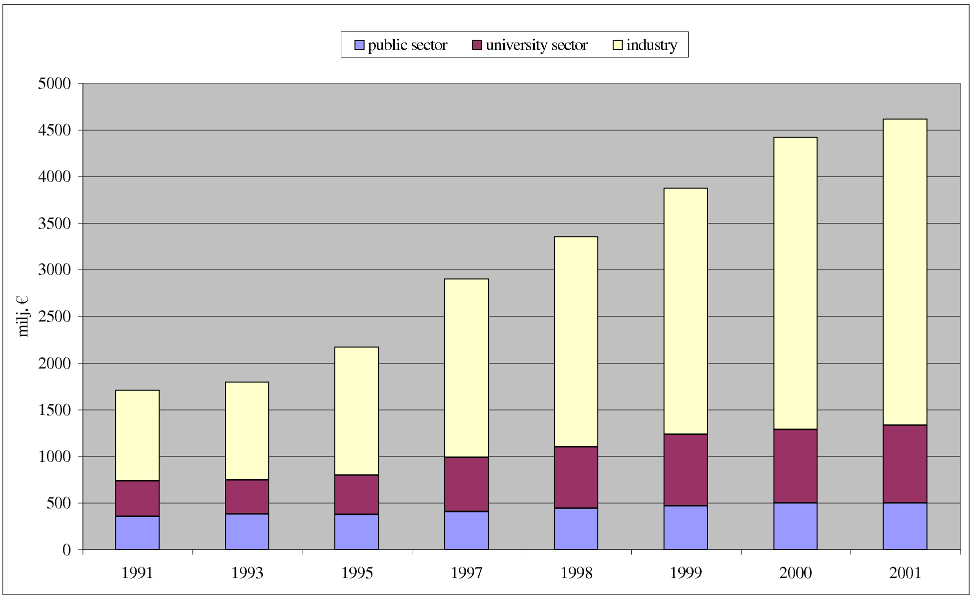

Figure 1: The development of R&D investment in Finland during 1991-2001 by sector (source: Statistics Finland)

which 1464 were business R&D projects.

Tekes was funded in 1983 in response to reforms in the Finnish science- and technology policy. The emergence of information technology was seen to provide new opportunities to the renewal of Finnish industry, which generated the need to strengthen the technology policy both in quantitative and qualitative terms (Lemola, 2002). R&D funding activities of the Ministry of Trade and Industry were transferred to Tekes and it became a central actor of the new technology policy.

90s, especially the latter half of the decade, witnessed a rapid growth in Finnish R&D investment (see Figure 1). Total Finnish R&D investment rose from 1.7 billion euros in 1991 to 4.4 billion euros in 2000. During the same period the GDP share of R&D investment rose from 2 % to 3.4 %.

Tekes took closely part in this development. Figure 2 shows the growth in Tekes business and public funding in the 90s. From 1990 to 2000 the overall funding by Tekes as well as the funding applications received by Tekes more than tripled. However, the share of business funding of the total funding provided by Tekes has been declining slightly over the decade. Business funding consists of business grants and subsidized loans. In the beginning of the decade the share

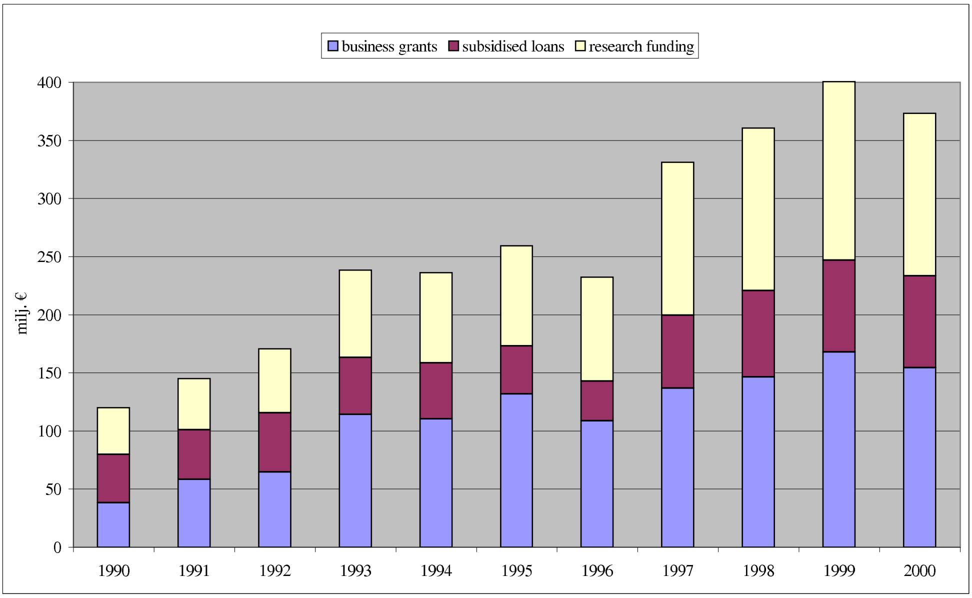

Figure 2: Research and business funding of Tekes in the 90s (source: Tekes Annual Reviews 1990-2000)

of business funding fluctuated between 67 and 70 percent compared to a range of 60-63 percent during the latter five years of the decade. In this paper the focus is on business R&D funding activities of Tekes.

In business funding especially the growth in R&D grants was pronounced in the 90s. The total amount of business grants quadrupled during the decade compared to a 90 percent growth in loan funding.

One clear trend in the business funding of Tekes during the 90s was the increasing emphasis on small and medium size firms (SMEs).[2] Figures 3 and 4 show that both in terms of applications received and amounts granted the relative share of SMEs grew steadily over the decade. The share of applications by firms with less than 100 employees increased from 36 % in 1990 to 69 % in 2000 and the share of business funding allocated to SMEs rose from 22 % in 1990 to 53 % in 2000.

Another trend in the 90s was the increase in technology programs.[3] Technol-

[2]An enterprise is considered a SME if 1) it has less than 250 employees, 2) large firms ownership is under 25 % and 3) its yearly turnover is less than 40 million euros or its balance sheet total is not over 27 million euros.

[3]Information about technology programs are from www.akseli.tekes.fi and a publication "Tekes in the 21st century Finland ".

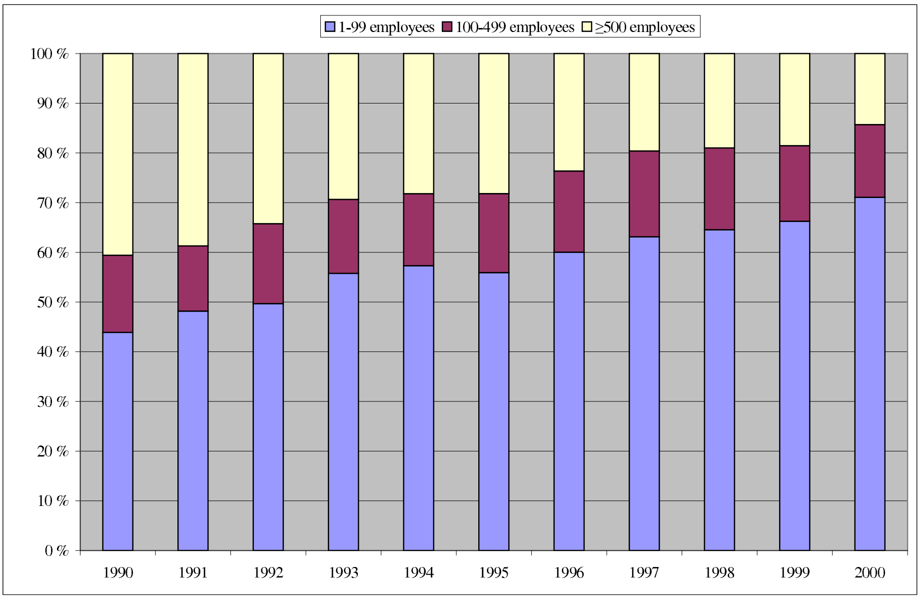

Figure 3: The share of business funding applications by size of the applicant firm during 1990-2000 (source: Tekes Annual Reviews 1990-2000)

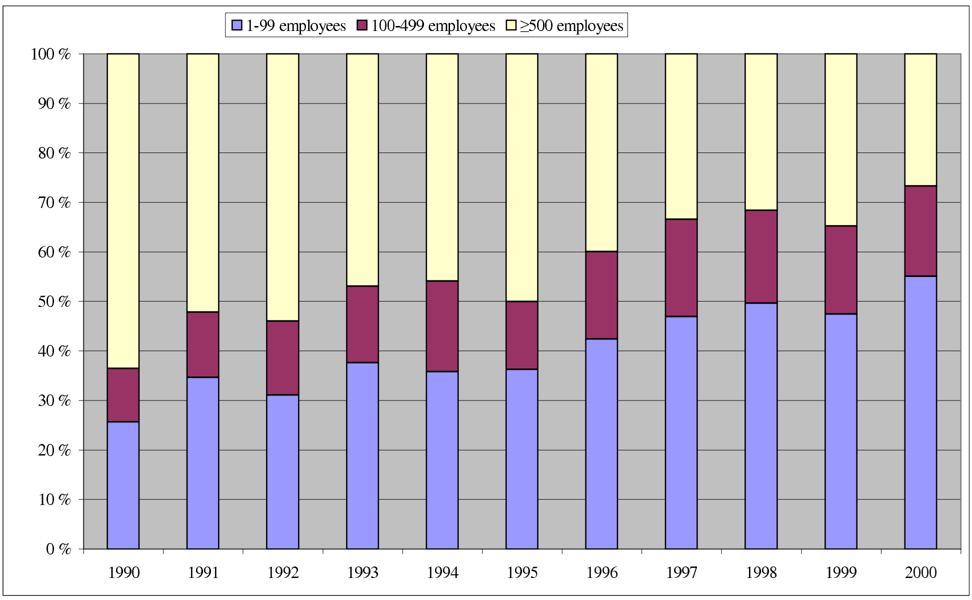

Figure 4: The share of granted business funding by size of the applicant firm during 1990-2000 (source: Tekes Annual Reviews 1990-2000)

ogy programs aim at strengthening key technologies and expertise from the perspective of Finland's future. In addition, technology programs hope to provide a tool for promoting collaboration, networking and the diffusion of technologies. Companies, research institutes and Tekes plan the technology programs in cooperation. Together they identify specific sectors of technology or industry that are perceived to need focused national support to boost the development of the sector and the diffusion of knowledge. In the beginning of the decade only slightly over 10 % of the total funding was allocated through technology programs compared to almost half toward the end of the decade.

The basic firm-level eligibility criteria for business R&D funding is that the firm is operating in Finland. Key funding instruments of Tekes are grants and low-interest loans. In 2004, 70 percent of the business R&D funding consisted of grants. In general the same funding criteria apply to both grants and subsidized loans. The key element determining the suitable funding instrument is the readiness of the output of a project to be introduced in the market markets: grants are directed to more basic research oriented R&D and R&D work done at the early phases of the innovation process. Subsidized loans and capital loans are aimed at R&D work in the later stages of the innovation process in which the focus is on developing a complete product or service that can be introduced in the market. In practice the distinction between different phases of the innovation process is not clear-cut and a project can incorporate both stages. As a result, Tekes funding can be a combination of several instruments.

Tekes subsidies constitute a competitive funding instrument. Technical advisers evaluate each project proposal and compare it to other project proposals. Since the amount of funding is limited, it is not enough for a project proposal to fulfill the Tekes criteria in order to get funding, but it must also succeed in the competition against other proposals. The evaluation is done compared to the relevant domestic and international reference group. In addition to the project, also the company is evaluated. Specific evaluation criteria are discussed in section 4.1.

3 Theoretical premises of R&D subsidies policies

The economic justifications for government intervention in the form of R&D subsidies to the private sector rely on the two familiar market failures that have to do with a) higher social than private benefits of R&D and b) the availability of market finance in the presence of asymmetric information. An identified market failure raises the question of whether government intervention could improve the situation. The efficiency of government intervention depends primarily on two issues:

1. Whether an appropriate policy instrument can be designed.

2. Whether this instrument is efficiently implemented.

Several policy instruments are designed to address one or both of the above market failures. Intellectual property rights are designed to improve the appropriability of knowledge and that way increase the incentives for R&D (see e.g. Hall, 2002 for a survey). Tax reliefs in turn aim for the same by reducing the cost of R&D (see Hall and Van Reenen, 2000). There are also public efforts to increase the functioning of financial markets (e.g. support to venture capital markets) in order to reduce possible financial constraints. A thorough overview and comparison of several technology and innovation policy instruments is, however, beyond the scope of this paper. In this paper the focus is purely on direct R&D subsidies. This section discusses the theoretical premises of the design and implementation of R&D subsidies.

3.1 Rationales for R&D subsidies

The main economic rationale used to justify government intervention in the form of R&D subsidies is that social benefits from R&D are higher than the private ones. Arrow (1962) showed that this is due to increasing returns, inappropriability of knowledge, and uncertainty. Below I shortly review each of the three components.

1. *increasing returns* - From a social point of view an efficient allocation of knowledge would require marginal cost pricing. In the presence of increasing returns this would imply a price equal to the cost of transmitting knowledge, which in many cases is close to zero. From a social point of view knowledge should be available at a very low cost or in some cases even freely available.

2. *inappropriability* - Inappropriability is a consequence of the non-rival and non-exclusive properties of knowledge. Because of non-rival and non-exclusive properties of knowledge, the private sector

cannot appropriate all the benefits from R&D activities, and thus has reduced incentives to engage in R&D.

Inappropriability of R&D activities and increasing returns are associated with positive spillovers and increased consumer surplus that generate higher social than private returns to R&D activities. In practice this means that it may be socially optimal to subsidize even an R&D project with negative expected private rates of return in order to turn it into a profitable one if it is associated with high social returns. Conversely, higher social benefits alone are not enough to justify subsidizing an R&D project with positive expected private rates of return, since private incentives would be enough to launch the project.

3. *uncertainty* - Innovative activities are often highly uncertain. In order to launch an uncertain innovation project, firm has to be willing to bear the risk inherent in the endeavor. The argument is based on the assumptions that in general firms are risk-averse, which leads to sub-optimal allocation of risk meaning that there will be discrimination against risky projects (Arrow and Lind, 1970). In other words, from a social point of view firms' preference for safer innovation projects gives rise to a loss of welfare.

The second rationale has to do with possible financial constraints due to asymmetric information. It is based on the argument that asymmetric information about the quality of a project (or a firm) between entrepreneurs and financiers, leads to a higher cost of external than internal capital (Leland and Pyle,1977 and Myers and Majluf, 1984). In the absence of internal funds, this may prevent firms from undertaking economically viable projects. It is argued that these informational problems may be particularly severe in relation to highly uncertain innovation projects. The development of financial markets has somewhat reduced the appeal of the financial constraints argument. However, empirical evidence suggests that R&D projects of especially young and small innovative firms may still face financing constraints (see e.g. Hall, 2002 for a survey).

3.2 Idealized design of R&D subsidies

Given that R&D subsidies aim at correcting the above market failures, the objective is to provide incentives for firms to launch innovation projects that are expected to be beneficial from the social point of view, but which the firms would not launch left on their own. In an ideal situation, the government acts as a benevolent social planner and allocates R&D subsidies to maximize social welfare. The government identifies innovation projects belonging to the target group, and subsidizes projects according to the difference between the social marginal return generated by a project and the opportunity cost of an additional subsidy euro. A project does not receive any subsidy if the marginal return of the project is smaller than the opportunity cost of an additional subsidy euro at the minimum subsidy level. The maximum subsidy is allocated to projects that generate marginal revenue equal to or larger than the opportunity cost at the maximum subsidy level. In between the minimum and the maximum subsidy levels, projects are subsidized up to the point where the marginal revenue is equal to the opportunity cost of an additional subsidy euro.

This ideal description of R&D subsidy programs is evidently extremely difficult to put in practice. First, how to determine the relevant target group? Second, how to identify those belonging to the target group? Third, how to calculate the optimal subsidy level? And fourth, how to ensure that the government is acting as a benevolent social planner? It is clear that there are no comprehensive answers to any of these questions. Here these questions are used to illustrate that even if there seems to be scope for government intervention from a theoretical point of view, it is not clear, whether the government can improve the situation in practice.

3.3 Government failure and bureaucratic decision-making

Government intervention always raises the question of whether an identified market failure is only replaced by a government failure. Is the government capable of making efficient allocation decisions to correct the market failure? In the case of R&D subsidies, the above discussion highlights that it is extremely unrealistic to assume that government intervention could lead to the optimal outcome. The difficult task is to determine whether a certain government intervention is justified when the distortions it brings are taken into account (Acemoglu and Verdier, 2000). Stiglitz (1998) argues that government intervention is warranted when it is possible to achieve a near-Pareto improvement, i.e. an improvement of which almost everyone benefits. The problem is that in general the outputs generated by government intervention are such that an objective measure of profitability and efficiency is extremely hard to obtain (Downs, 1965 and McFadden, 1975)

There are two decision-making levels involved in government intervention: political and bureaucratic. Usually the general goal of the intervention is determined by political decision making, while government bureaucrats are responsible for the actual implementation. As McFadden (1975) points out, often the general goal set by politicians consists of vague statements like maximizing public welfare, and bureaucrats are left with considerable freedom in translating this goal into concrete decision rules. This seems to apply also to technology policy. In Finland the general long term goals given to Tekes by the Ministry of Trade and Industry are: the strengthening of the Finnish knowledge-base through R&D activities, internationalization of innovation activities, success of innovative growth-companies, increase in productivity and renewal of the business sector, regional development, and increase in the societal well-being through innovation activities (www.tekes.fi , in Finnish only). Given that bureaucrats have considerable freedom in making the allocation decisions, the focus in this study is on bureaucratic decision-making and problems related to political decision-making are not discussed further.

There are three main issues underlying the possible government failure related to R&D subsidy policies. The first issue concerns the target group for the policy. Even if there is assumed to be room for government intervention in the form of R&D subsidies, it is an open question of what kind of activities should be subsidized and how to identify those projects. From a theoretical point of view projects with higher social benefits than private ones should be subsidized. Which are these projects in practice and how to identify them? It is clear that bureaucrats face informational problems in making the allocation decisions, but an open question is whether these informational problems are so severe that a specified market failure cannot be adequately addressed in practice.

The second issue has to do with the incentives that govern bureaucratic decision making. What is it that the bureaucrats are maximizing? Are the bureaucrats motivated merely by goals that benefit only themselves or are they indeed interested in maximizing social welfare as a benevolent social planner should be. Corruption is one force that can distort the bureaucratic behavior. It is possible the bureaucrats make unwarranted subsidy decisions in order to get something useful in return, e.g. a service at a low price or a favorable post at a company. Heckman, Heinrich and Smith (1997) conversely discuss whether performance standards provide incentives that point possibly self-interested bureaucrats to the "right" direction or do they lead e.g. to "cream-skimming". Niskanen (1968) suggests that bureaucrats are more interested in maximizing the overall budget of their bureau than social welfare. In addition, lobbying by different interest groups could divert the decision-making of government bureaucrats.

The third issue is related to the general equilibrium effects of an R&D policy. Namely, are there associated negative externalities that undermine the positive effects of spillovers?[4] In other words, to what extent subsidizing some projects generate distortions that harm the non-subsidized? This is related to the near-Pareto improvement - are almost everybody benefiting from the subsidy policy or in other words, do the gains from the policy outweigh the losses? It may be for example that subsidies create unwarranted competitive advantage to some firms. Or at the technological level, is it possible that a more promising technology is left unexplored, because subsidies made the exploration of another related technology more attractive?

Given the above problems related to government intervention and the difficulty of assessing the presence and magnitude of these problems, it is not clear whether government intervention is warranted. As Acemoglu and Verdier (2000) point out, some would prefer to live with the market failures, while others are willing to accept that there is a trade off between government failure and market failure. From a welfare point of view government intervention may be in some cases optimal even though it is associated with government failure. In relation to corruption, Acemoglu and Verdier show that government intervention with partial corruption is optimal, if corruption is relatively rare and the market failure in question is relatively important.

Although this study does not allow extensive analysis to any of the above questions, it touches upon the first two issues. A detailed examination of Tekes subsidy program reveals how Tekes perceives the scope of R&D subsidies and to what extent this view is in line with the theoretical rationales. An analysis of the determinants of acceptance in turn reveal how the official evaluation criteria are reflected in the Tekes decision-rule - does Tekes behave as it preaches in the light of official evaluation criteria. In addition, analysis by different decision-making levels indicate whether the decision-rules of different decision-making level appear to differ from each other.

[4] An obvious addition to the list would be, do the costs of putting up and administering an R&D subsidy program outweigh the benefits. Although relevant, this question is omitted here.

4 R&D subsidies in practice - the Finnish example

4.1 Design of the R&D subsidy program

There seems to be three main themes underlying the design of the business R&D subsidy program of Tekes: risk, co-operation and small and medium size enterprises (SMEs). In the following I discuss each of them separately.

In the Annual Review 2005 Tekes puts forward the following statements: [5]

> *The R&D funding of Tekes is allocated to projects that produce directly or indirectly in the long run the greatest possible benefit for the national economy and society in relation to public investment.*
>
> *In corporate projects the core value added of Tekes is generated from the sharing of the risk involved in a project. This launches bigger innovation development leaps than would occur without public funding and increases companies' own contributions.*
>
> *R&D funding of Tekes encourages companies to engage in controlled risk-taking.*

The first statement highlights that in general the aim is to allocate funding to projects that are likely to generate the greatest social benefit. The next two statements in turn indicate that in the case of business funding the main role of Tekes is to share risks and that way to encourage firms to undertake riskier projects than they otherwise would. Implicitly these statements put forward an argument that without public support, firms are likely to play safe and engage in safe innovation projects, whereas the risky innovation projects would be profitable from a welfare point of view. The following extracts describe what is the risk Tekes is talking about.

> *R&D funding of Tekes shares the technological, funding and commercial risk involved in a project (Tekes Annual Review 2005).*
>
> *The funding of Tekes is intended for challenging and innovative projects, some of which will hopefully lead to global success stories* (www.tekes.fi/eng/tekes/rd, accessed 31/08/06*).*

[5] There are no major changes in the objectives of the Tekes funding policy with regard to business R&D funding in between the sample period in question and the year 2005. As a result the description of the objectives of the funding policy in 2005 applies also to the sample period in question, (January 2000 - June 2002).

Tekes especially promotes innovative, risk-intensive projects (www.tekes.fi/eng/, accessed 01/09/06).

It seems that the risk Tekes is interested in has to do with challenging and innovative projects with high business potential but also with high uncertainty. This attitude toward risk is directly built into the public funding criteria a), b) and c) listed below.

a) *the business activity to be pursued* - The goal is to promote projects that generate profitable business opportunities for global markets.

b) *the technology, innovation or competence to be developed* - The technology, innovation or competence to be developed should be technologically new and challenging at least to the company itself. In addition, knowledge and know-how created within the project should generate long lasting competitive advantage to the company. Also internationally high-level challenges are appreciated.

Funding criteria c) below further highlights where the risk should be - not in the resources needed to implement the project, but in the content of the project.

c) *the resources reserved for the proposed project* - To be realistic the project proposal should incorporate adequate human and economic resources and the company should have a sound financial standing.

Although it is ambiguous what innovative, challenging and risk-intensive really means, this carries an implicit assumption that innovation projects generating new knowledge with significant commercial potential, but also with high probability of failure are expected to be the ones that need public support.

In economic terms a mean-preserving spread could be used to characterize the concept of risk-taking in this setup. Assume that a firm has two projects that generate the same expected return. However, the dispersion of the possible outcomes differ between these two projects. The possible outcomes related to the less risky project are centered around the expected return. In other words the probability that the less risky project generates a considerably larger or smaller return compared to the expected one is small. The possible outcomes related to the more risky project are in turn more dispersed compared to the less risky project. The probability of the more risky project to generate a return considerably higher than the expected one is larger than that of the less risky project. The probability of generating outcomes with significantly smaller returns compared to the expected one is higher for the more risky project. A risk-averse firm chooses the less risky project, whereas the public agency would want the firm to choose the more risky one that has a higher probability of generating 'a global success story'.

This kind of support to risk-taking can find support in the uncertainty argument presented in section 3.1. According to the rationale, the uncertainty inherent in innovation leads risk-averse firms to under-invest in risky R&D activities. In addition the financial constraints argument could be used to argue that because of asymmetric information, risky projects are likelier to suffer from financing constraints. However, it should be borne in mind that these rationales depend on two crucial assumption: firms are risk-averse in relation to R&D activities and asymmetric information creates financial constraints.

Second theme underlying the design of Tekes R&D subsidy program is co-operation. Almost half of the Tekes funding is steered through technology programs that are especially designed to promote co-operation as the following extracts indicate.

> *The technology programs of Tekes play an important role in strengthening close collaboration and networking between companies, universities and research institutes* (Tekes Annual Review 2005).
>
> Technology programs are *Forums for exchange of information and networking between companies and research communities* (http://www.tekes.fi/english/programmes/what/what.html, accessed 05/09/06).

The aim to encourage networking and collaboration among different actors is also explicitly stated in the public funding criteria d) and e) below.

d) *co-operation within the project* - One central aim of Tekes funding is to promote both domestic and international networking with other companies, universities and research centers.

e) *the effect of Tekes funding on the project* - The aim is that with Tekes funding the companies are willing to carry out more challenging R&D projects than they otherwise would and that by providing resources for efficient networking the funding enhances the widespread use of the benefits of the project in the Finnish economy.

The rationale supporting the emphasis on co-operation is evidently spillovers. Spillovers generate appropriability problem for firms, but from a purely welfare point of view, the more new knowledge spills over the better. By encouraging networking and collaboration the aim is to increase spillovers. The goal is on the one hand to enhance spillovers that increase the social return and on the other hand, to bridge the gap between the private and social returns with the subsidy, so that firms are willing to undertake these collaborative projects. The underlying assumptions here are that with subsidies, firms engage more in co-operation than they would without subsidies, and that the kind of co-operation generated within subsidized projects enhances spillovers that are valuable to the society.

The third central element in the design of Tekes R&D subsidy program is the emphasis on SMEs. The emphasis on SMEs was reflected in the share of Tekes funding allocated to SMEs as shown in section 2. In the design of the subsidy program the main indication of the emphasis on SMEs is that the requirements imposed on larger firms are more stringent. Large firms' projects should fulfil at least one of the following criteria: networking with SMEs and universities or research institutes, participation in a technology program, participation in an international R&D project and network, project consists mainly of industrial research, or research outcomes are public (http://www.tekes.fi/rahoitus/yritys/suuryritykset_tuotekehitysrahoitus.html, accessed 05/09/06, in Finnish only). Apparently, subsidies to larger firms with additional requirements designed to increase the spillovers are regarded justified on the basis that they provide incentives for large firms to "allow" spillovers of the created knowledge. In addition, as mentioned in section 2 the upper bound for the subsidy is lower for firms not fulfilling the official SME criteria.

The basic rationales underlying business R&D subsidies do not differentiate between large and small firms. However, there are several arguments why especially SMEs may suffer more from the identified market failures. To begin with, the risk-aversion may be more sever in the case of SMEs focusing on one or few projects compared to large firms with project portfolios containing whole range of projects. Trajtenberg (2001) also highlights that the relative lack of competencies and experience, complementary to R&D, can make a project conducted in a small firm riskier compared to what it would be if conducted in a large firm. In addition it is argued that SMEs suffer relatively more from the inappropriability problems related to R&D activities, because they cannot internalize the spillovers (Trajtenberg, 2001 and Gans and Stern, 2000). Also the financial constraints argument is more probable for SMEs. As noted in section 3.1, it is especially small, innovative firms that may suffer from financial constraints.

There is one more element in the design of Tekes subsidy program worth noting that is especially relevant in relation to technology programs. According to Tekes technology programs are also *targets with greatest impact chosen for R&D financing* (http://www.tekes.fi/english/programmes/what/what.html, accessed 05/09/06). This points yet another way Tekes attempts to increase the social return to R&D: mission-oriented targeting to specific areas in which the social return is expected to be especially high. The same idea is behind the final public funding criteria.

f) *societal benefits of the project* - Societal benefits that favor Tekes funding are: positive environmental effects, balanced regional development, amelioration of the Finnish working and living conditions, improvements to back up the development of social welfare and health-care, promotion of the national energy strategy and promotion of equality.

However, even in the case of technology programs the targeting seems to mostly provide a common framework under which different parties that could be expected to benefit from each other can be organized. It is not that much about providing mission-oriented funding to narrowly specified targets. As a result I conclude that risk-sharing, enhancing co-operation and focusing on SMEs are the driving forces underlying the design of Tekes R&D subsidy program to the business sector. The hypothesis is that these emphases stand out in the empirical analysis. Tekes does not explicitly justify its objectives, but the economic rationales at least implicitly provide some support to them.[6]

4.2 The decision-making process within Tekes[7]

The decision-making process within Tekes starts with allocating an application to a relevant technology field. In general, the relevant technology field is the one

[6] One issue not tackled here is that the optimal solution to different objectives may call for different kinds of instruments. As mentioned above, Tekes uses grants and low interest loans as its main instruments. However, given that a large majority of Tekes funding consists of pure grants it seems reasonable to focus here on subsidies in general and leave the comparison of different instruments to future work.

[7] The description of the decision-making process is based on internal material of Tekes and discussions with Tekes employees to which the author had access during an 11-month stay at Tekes in 2002. The description reflects the decision making process during the sample period in question.

Table 1: Decision-making levels within Tekes

Amount related to the proposal	Decision-maker
≤ 150 000 / 200 000 €	Head of the technology field
≤ 500000	Process-leader
≤ 1700000	Director general
> 1 700 000 €	Board

that has the best technological and industry knowledge related to the project proposal. The technology field then sets up a group that takes care of the treatment of the application. This group is responsible for the evaluation of the project proposal, and based on its evaluation the group prepares a funding proposal with key arguments supporting the proposal.

The decision-making process within Tekes has several stages depending on the applied amount. Table 1 below presents different decision-making levels with the associated upper limits for the decision-making rights.[8]

First the funding proposal of the group is treated in the decision making meeting of the technology field. The group presents the funding proposal and related arguments, which are then discussed. Depending on the applied amount, the technology field either makes the final funding decision, or decides on whether the funding proposal can be forwarded to the next stage. Based on the discussions, the decision maker of the technology field makes the final decision.

If the applied amount is such that the technology field only decides on forwarding the funding proposal, the next stage is the decision making meeting of the process in question. In this meeting the group again presents the funding proposal, which is then discussed. Based on discussions the leader of the process makes the decision. Again depending on the applied amount either the decision is the final funding decision or the process leader decides on forwarding the proposal to the next decision making level that is the decision making meeting of the director general.

In this meeting the process leader instead of the project group presents the funding proposal to the director general, who then makes the decision. Again,

[8]Sometimes a specific decision-maker decides to forward the decision to the next decision-making level even if the applied amount would allow her to make the final decision. This may happen for example if the project in question presents a test case not dealt with before.

depending on the applied amount either the decision is the final funding decision or the director general decides on forwarding the proposal to the final decision making level, the board. The board is legally the only collective decision-making unit. Unless the chair of the board disagrees, the board discusses only approving proposals. The chair of the board is informed about rejections before the meeting of the board, and if the chair sees it necessary, the refusal is handled in the board meeting.

Although the official decision-maker is an individual except in the case of the board, the decision-making process is in practice highly collective. To start with, it is not a single person that is responsible for the evaluation of the projects, but a project group consisting of several employees. In addition, usually several project proposals are dealt with at each decision-making meeting and the discussion concerning a project proposal is open to all participating Tekes officials - not only the project group and the decision-maker. This collective character of the decision-making process reduces the possibilities to make funding decisions based on an individual's own self-interests, given that the self-interests are not in line with the goals of the organization. What remains, though, is the possible ambiguity at the organizational level.

5 The econometric setup

The starting point of the econometric analysis is to present key ingredients of an analytic model underlying the decision-rule of the government. Takalo, Tanayama, and Toivanen (TTT) develop this model in the first essay. Here the aim is not to end up with a structural econometric model to be estimated. Rather the model serves as a general framework that helps understanding what the actual estimations deal with. A thorough treatment of the model can be found in the first essay.

The situation TTT model is the following. There is a pool of potential applicants who have projects that require costly investments. The applicants need to decide whether or not to apply to a subsidy program. A subsidy lowers the marginal (shadow) cost of the investment, and all agents know the effect of the subsidy. The program is run by a public agency whose utility function includes applicants utility as an argument. The agency decides what subsidy to give to each actual applicant, subject to constraints.

TTT model the subsidy program as a four-stage game of incomplete information between the applicant and the agency. In stage zero, nature draws the types of the players from a common knowledge prior distribution. In stage one, the applicant decides whether or not to apply to the program. In stage two, the agency decides the level of subsidy. In stage three, after receiving the treatment, the applicant makes the investment in project i that depends on the level of subsidy. Below I cover the main ingredients of the model that are essential in understanding how the decision-rule of the agency (or in the vocabulary of this paper, the government) comes about.

The utility to the government from project i depends on the applicant's utility (private benefits), the expected benefits to the government not captured by the applicant's utility function, the opportunity cost of the subsidy euros and the sum of the fixed costs of applying and processing the application. The specific form of the government agency's utility function is presented in TTT. The decision-rule of the government is the solution to the government's maximization problem. The government chooses the subsidy level s_i to maximize its expected utility. By making some functional form assumptions the optimization problem of the government bureaucrats yields the following unconstrained decision-rule (see TTT for details):

$$s_i^* = 1 - g + Z_i\delta' + \eta_i. \tag{1}$$

g is the constant opportunity cost of the agency's resources. Z_i is a vector of observable applicant and project characteristics that affect the expected benefits from the project to the government not captured by the applicant's utility function. Z_i captures the effects of the applicants investment on the agency beyond the applicants utility and the direct costs of treatment and the application process. δ in turn is the parameter vector reflecting the effect of Z_i on the subsidy. Note that within the framework of the TTT model these coefficients can be interpreted as the marginal effects of R&D on the benefits accruing only to the government. The subsidy is a share of the investment cost, and it is subject to minimum and maximum constraints. In the case of Tekes the upper bound for the subsidy share differs between SMEs and larger firms. If a firm fulfils the EU SME criterion (see footnote 2) , the upper bound is 0.6, otherwise 0.5. The lower bound is zero. η_i is the unobserved (by the econometrician) error term. In this study the error term is assumed to follow a normal distribution and to be uncorrelated with applicant characteristics. TTT test the robustness of this distributional assumption in their work by applying a non-parametric CLAD estimator proposed by Powell (1984) to two-limit Tobit model. They do not find evidence against the normality assumption.

This paper concerns equation (1). The estimable equation builds directly on equation (1) with two modifications: the minimum constraint of 0 and the maximum constraint of $\bar{s}$ are taken into account and the opportunity cost g is embedded in the overall constant of the estimated equation and thus cannot be identified. This yields the following econometric model to be estimated:

$$s_i = \begin{cases} 0, & \text{if } s^* \leq 0 \\ Z_i\delta + \eta_i, & \text{if } 0 < s^* < \bar{s} \\ \bar{s}, & \text{if } s^* \geq \bar{s} \end{cases} . \tag{2}$$

As can be noted, equation (2) is censored both below zero and above $\bar{s}$. There is a positive probability mass at zero and at $\bar{s}$ whereas in between, s_i is continuous. As a result equation (2) is estimated as a two-limit Tobit model. Given that the paper focuses on descriptive econometric analysis - i.e. on analyzing empirically what the decision-rule looks like - I also estimate alternative specifications. More specifically, in addition to the two-limit Tobit, I estimate specifications in which the decision-rule consists of two stages. The first stage describes the acceptance decision: whether the application is accepted or not. In the second stage, the decision on the subsidy level is made. In other words, I allow for the possibility that the characteristics Z are differently related to the acceptance decision and to the subsidy decision.

6 Data

Originally the data contain all the business sector applications for R&D subsidies Tekes received from January 1st 2000 to June 30th 2002 and consist of detailed information on the project proposal, the applicant firm and the funding decision of Tekes. This original data covers 3512 applications from 2168 firms. However, Tekes started the extensive collection of project level data in 2001. After cleaning the data of missing values we are left with 1237 projects that constitute the sample analyzed in this paper. 1095 of the applications within the sample, almost 90 percent, are from the years 2001 or 2002 and in total 60 percent of the applications received in 2001 or 2002 are covered by the sample.[9]

[9] In order to analyze whether there appears to be some systematic differences between all the applications and applications covered by the sample used, I did some basic comparisons of

Table 2: The share of each instrument of the total funding applied and allocated

	Applied		Granted	
	all	sample	all	sample
Total sum, million €	1325	523	606	241
Share of subsidies	84 %	82 %	65 %	64 %
Share of loans	8 %	7 %	20 %	20 %
Share of capital loans	8 %	11 %	15 %	15 %

6.1 The dependent variable

As mentioned in section 2, Tekes funding can be a combination of several instruments. Tekes grants subsidies, subsidized loans and subsidized capital loans. The granted funding can be a pure subsidy, a pure loan, a pure capital loan or a subsidy combined with either a loan or a capital loan. Tekes subsidized loans not only have an interest rate below the market rate but they are also soft: If the project turns out to be a commercial failure, the loan may not have to be paid back. A subsidized capital loan granted by Tekes differs from the standard private sector debt contract in various ways: it is included in fixed assets in the balance sheet, it can be paid off only when unrestricted shareholders equity is positive, and the debtor does not have to give collateral for the loan. Table 2 below shows the share of each instrument of the total funding applied and allocated to business R&D for the original data and the sample used in this paper. The figures indicate that subsidies cover over 80 % of the applied amount while the corresponding figure for granted funding is around 65 %. Some 27 % of the applications are rejected.

Tekes grants subsidies ex ante as a share of to-be-incurred R&D costs. In the application the applicant reports the anticipated costs of the projects. Sometimes Tekes adjusts this proposed budget, both down and up, when an applicant, e.g., applies subsidies for costs that Tekes cannot cover. In practice an upward adjustment is rare and in principle occurs only if a project significantly changes character during the application process. To-be-incurred R&D costs refer to the costs accepted by Tekes and in the following are called "accepted costs". The actual funding then covers the promised share of incurred costs up to a specified euro limit.

The dependent variable used in this paper is the effective subsidy-intensity

frequencies across industries, size classes, funding decisions, granted amounts, etc. No major differences were found.

of the granted funding. Effective means that instead of taking into account the absolute value of a loan, only the "subsidized" part of a loan is considered. This is the estimated difference between a market loan and a corresponding Tekes loan. In order to calculate the the subsidy-intensity of each decision using the exact formula, one would need information on the loan period, redemption free years and interest rates. Unfortunately, the data available has information only on the absolute amount granted. However, Tekes provided me with illustrative subsidy-intensity calculations using a loan period of six years with three redemption free years. These exemplar calculations were used to derive the following approximation of the subsidy-intensity.

$$s_i = (grant + 0.2 * loan + 0.1 * capital\ loan)/(accepted\ costs). \qquad (3)$$

This is the dependent variable used in the analysis. The mean subsidy-intensity of the successful applications in the sample is 0.31.

6.2 Explanatory variables

Table 3 contains descriptions of the explanatory variables. Explanatory variables consists of both firm-level and project-level characteristics. *CHALLENGE* and different project-level *RISK*-variables are evaluations of the technical advisers of Tekes, and according to Tekes they are the key evaluation criteria in the decision-making. *EU-SUPPORT REGION* is added to control for the fact the projects from firms locating in these support regions are entitled to a 5 to 10 percentage points higher subsidy than a comparable project from other regions. Explanatory variables are chosen so that they capture the key characteristics that are likely to affect the subsidy-decision of Tekes.

From Table 4 we see that compared to applicants with rejected applications firms that have successful applications are on average larger in terms of number of employees, have higher sales per employee, more exports and more R&D investment, and have higher success rate in their earlier applications. When looking at the project characteristics we can notice that successful project proposals are technologically more challenging and have higher technological risk whereas risk related especially to the economic stance of the applicant firm is on average lower. In addition, successful project proposals incorporate on average more research and firm partners, and the overall size of the project proposal, measured as costs proposed by the applicant, is on average larger for successful applications compared to rejected ones.

Table 3: Description of the explanatory variables

Variable	Description
Firm-level	
AGE	Age of the firm.
EMPLOYEES	No of employees.
SALES_EMPL	Sales per employee for the year preceeding the application, thousands of €*.
GRANT/APPL	No of applications accepted before the year 2000 / the total number of applications sent before 2000.
SME	Dummy indicating whether the firm is a SME.
PARENT	Dummy indicating whether the firm is a parent company.
R&D	R&D investments for the year preceeding the application, thousands of €*.
R&D_DUM	Dummy indicating whether the variable *R&D* is greater than 0.
EXPORT	Exports for the year preceeding the application, thousands of €*.
EXPORT_DUM	Dummy indicating whether the variable *EXPORT* is greater than 0.
Project-level	
CHALLENGE	Technological challenge of the project, values from 0 to 5.
RISK_COMPETENCE	Project's risk related to the resources reserved for the project , values from 0 to 5.
RISK_ECONOMIC	Project's risk related to the economic stance of the firm , values from 0 to 5.
RISK_TECHNOLOGICAL	Project's risk related to the technology to be developed , values from 0 to 5.
RISK_MARKETS	Project's risk related to the market opportunities of the output, values from 0 to 5.
NOVELTY_TECH	Dummy indicating whether the technology to be developed is new to the applicant.
NOVELTY_APPL	Dummy indicating whether the application to be developed is new to the applicant.
NOVELTY_BUSINESS	Dummy indicating whether the business activity to be developed is new to the applicant.
RESEARCH_PARTNERS	No of research partners.
FIRM_PARTNERS	No of firm partners.
PROJECT_SIZE	Proposed costs of the projects, thousands of € .
TECH_PROGRAM	Dummy indicating whether the application is for a technology programme.
EU-SUPPORT REGION	Dummy indicating whether the application is from EU-support region.

* If the figure for the preceeding year was not available, the nearest available figure of the preceeding years back to 1999 was used. There are in total 62 applications for which the preceeding year was not available.

Table 4: Descriptive statistics

	All (1237)					Successful applicants (903)					Rejected applicants (334)				
Firm-level	Mean	Median	Std. Dev.	Min	Max	Mean	Median	Std. Dev.	Min	Max	Mean	Median	Std. Dev.	Min	Max
AGE	18.45	10	24.11	0	113	19.03	10	24.56	0	106	16.89	10	22.80	0	113
EMPLOYEES	2823.92	32	10524.21	0	60289	3032.14	34	10943	0	60289	2260.97	25	9277.36	0	60289
SALES_EMPL	220.59	98.38	1738.42	0	43200	255.37	102.86	2031.90	0	43200	126.50	86.15	147.78	0	1495.29
GRANT/APPL	0.57	0.78	0.43	0	1	0.60	0.82	0.43	0	1	0.49	0.57	0.44	0	1
SME	0.72	1	0.45	0	1	0.71	1	0.45	0	1	0.75	1	0.44	0	1
PARENT	0.14	0	0.35	0	1	0.15	0	0.36	0	1	0.10	0	0.30	0	1
R&D	88600	300	468000	0	2980000	94800	350	487000	0	2980000	71900	137.20	413000	0	2980000
R&D_DUM	0.83	1	0.38	0	1	0.85	1	0.36	0	1	0.78	1	0.42	0	1
EXPORT	532000	185	2380000	0	1.4E+07	581000	258.1	2480000	0	1.4E+07	399000	46420	2080000	0	1.4E+07
EXPORT_DUM	0.65	1	0.48	0	1	0.67	1	0.47	0	1	0.58	1	0.49	0	1
Project-level															
CHALLENGE	3.40	4	1.02	0	5	3.67	4	0.83	0	5	2.67	3	1.10	0	5
RISK_COMPETENCE	1.45	1	0.84	0	5	1.42	1	0.78	0	4	1.54	1	0.98	0	5
RISK_ECONOMIC	1.29	1	1.10	0	5	1.20	1	0.97	0	4	1.55	1	1.36	0	5
RISK_TECHNOLOGICAL	2.13	2	0.93	0	5	2.27	2	0.87	0	4	1.74	2	0.98	0	5
RISK_MARKETS	2.27	2	0.98	0	5	2.25	2	0.95	0	4	2.33	2	1.07	0	5
NOVELTY_TECH	0.36	0	0.48	0	1	0.39	0	0.49	0	1	0.29	0	0.46	0	1
NOVELTY_APPL	0.33	0	0.47	0	1	0.34	0	0.47	0	1	0.30	0	0.46	0	1
NOVELTY_BUSINESS	0.40	0	0.49	0	1	0.40	0	0.49	0	1	0.40	0	0.49	0	1
RESEARCH_PARTNERS	1.34	1	1.26	0	8	1.48	1	1.27	0	8	0.98	1	1.14	0	8
FIRM_PARTNERS	2.57	2	1.90	0	9	2.67	2	1.96	0	9	2.29	2	1.71	0	8
PROJECT_SIZE	909.80	383.44	1862.15	10.64	27000	997.98	420.47	2059.17	13.96	27000	671.40	287.96	1143.37	10.64	11200
TECH_PROGRAM	0.46	0	0.50	0	1	0.49	0	0.50	0	1	0.49	0	0.49	0	1
EU-SUPPORT REGION	0.24	0	0.42	0	1	0.24	0	0.43	0	1	0.42	0	0.42	0	1

7 Estimation results

7.1 The two-limit Tobit model

Table 5 presents the estimation results for the two-limit Tobit model. The Table covers four specifications with different sets of explanatory variables in order to analyze how the model behaves as additional regressors are added. The left-most column consists of the simplest specification with only firm-level regressors. In the second column the key project-level evaluation criteria are added. In the third column additional project-level characteristics related to the funding criteria of Tekes are added. In addition three variables are added to control for the effect of project size, participation in a technology program and belonging to a support region. Finally in the fourth column also industry dummies are added.

When looking at the coefficients and the values of the log-likelihood function, it can be noted that the main change occurs between the first and the second column when the key project-level evaluation criteria are added. There are considerable changes in the size and the statistical significance of the firm-level explanatory variables and the value of the log-likelihood function increases substantially, which is reflected in the high value of the likelihood-ratio test statistic (T_{LR}) . This indicates the importance of these key project characteristics in analyzing the subsidy-intensity.

Inclusion of additional project level characteristics in the third column seems to improve the fit of the model as the log-likelihood function increases significantly. According to the likelihood-ratio test statistic (T_{LR}) these additional regressors are jointly significant in the model. With the exception of *NOVELTY_APPL*, they also obtain statistically significant coefficients. A comparison between the second and the third column indicates that the coefficients of the previously introduced firm-level and key project-level characteristics remain stable. Together these observations suggest that these additional project level characteristics have an independent role in explaining the subsidy-intensity.

The fourth column indicates that also the industry dummies have an independent role in explaining the subsidy intensity. Industry dummies are added to control for industry specific effects that might affect the subsidy-intensity. This kind of an effect could arise if there was for example relatively more funding allocated to a specific industry through technology programs in the sample period. Given that the interest is not in interpreting the effect of the industry

Table 5: Estimation results of the two-limit Tobit model

Variable	Subsidy-intensity			
CONSTANT	**0.1197**	**-0.1551**	**-0.2381**	**-0.2687**
	(-0.0266)	(0.0355)	(0.0374)	(0.0411)
Firm-level				
AGE	**0.0009**	**0.0008**	**0.0008**	**0.0007**
	(0.0004)	(0.0004)	(0.0003)	(0.0003)
*EMPLOYEES**	-0.0001	-0.0002	-0.00005	0.00002
	(0.0003)	(0.0002)	(0.0002)	(0.0002)
*SALES_EMPL***	0.0004	-0.0001	-0.00004	-0.0001
	(0.0004)	(0.0003)	(0.0003)	(0.0003)
GRANT/APPL	**0.0575**	**0.0265**	0.0246	**0.0278**
	(0.0173)	(0.0155)	(0.0152)	(0.0153)
SME	0.0016	**0.067**	**0.0733**	**0.0748**
	(0.0195)	(0.0179)	(0.0179)	(0.0181)
PARENT	**0.0466**	0.0209	0.0142	0.0074
	(0.0280)	(0.0248)	(0.0244)	(0.0246)
*R&D****	-0.0006	-0.0004	-0.0002	-0.0001
	(0.0006)	(0.0005)	(0.0005)	(0.0006)
R&D_DUM	-0.0042	**-0.0447**	**-0.0387**	**-0.0421**
	(0.0193)	(0.0174)	(0.0171)	(0.0170)
*EXPORT****	0.0001	0.0001	0.000003	-0.00003
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
EXPORT_DUM	**0.0307**	0.0204	0.0170	**0.0250**
	(0.0157)	(0.0141)	(0.0141)	(0.0144)
Project-level				
CHALLENGE		**0.0902**	**0.0950**	**0.0970**
		(0.0071)	(0.0073)	(0.0074)
RISK_COMPETENCE		-0.0066	-0.0069	-0.0073
		(0.0082)	(0.0080)	(0.0080)
RISK_ECONOMIC		**-0.0468**	**-0.0437**	**-0.0412**
		(0.0070)	(0.0069)	(0.0069)
RISK_TECHNOLOGICAL		**0.0436**	**0.0362**	**0.0363**
		(0.0076)	(0.0077)	(0.0077)
RISK_MARKETS		**-0.0176**	-0.0106	-0.0111
		(0.0069)	(0.0070)	(0.0070)
NOVELTY_TECH			**0.0407**	**0.0401**
			(0.0129)	(0.0129)
NOVELTY_APPL			0.0051	0.0052
			(0.0134)	(0.0134)
NOVELTY_BUSINESS			**-0.0231**	**-0.0232**
			(0.0136)	(0.0136)
RESEARCH_PARTNERS			**0.0127**	**0.0138**
			(0.0051)	(0.0053)
FIRM_PARTNERS			**0.0097**	**0.0102**
			(0.0031)	(0.0032)
PROJECT_SIZE			**-0.00001**	**-0.00001**
			(0.000003)	(0.000003)
TECH_PROGRAM			**0.0228**	**0.0223**
			(0.0120)	(0.0121)
EU-SUPPORT REGION			**0.0457**	**0.0492**
			(0.0141)	(0.0146)
Industry-dummies				YES
Obs.	1237	1237	1237	1237
log-likelihood	-274	-112	-84	-73
T_{LR}		324	32	22
Prob > $\chi2$(df)		0.0000	0.0000	0.0212
df		5	8	11

* Measured in 100 employees. **Measured in 100 000 euros. ***Measured in 10 000 000 euros.

Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.

T_{LR} = likelihood-ratio test statistic, Prob = p-value , df = degrees of freedom.

dummies as such, the results related to them are reported in Appendix 1. In further estimations it is only indicated whether the industry dummies are included as regressors or not. Industry dummies were always included in the first place, but if they did not turn out to be jointly statistically significant, they were excluded.

7.2 The two-part model

In order to allow for the possibility that the subsidy decision is actually made in two steps - the first step determining whether an application is accepted or rejected and the second step determining the subsidy-intensity - I estimated a two-part model. In the two part model the acceptance decision is modelled as a probit model and the subsidy-intensity decision is modelled as a truncated from below and censored from above regression model. Estimation results of the two-part model are presented in Table 6.

A likelihood ratio test clearly rejects the two-limit model in favor of the two-part model. The likelihood ratio statistic gets a value of 381. To get an indication of the possible correlation between the error terms in the acceptance - and subsidy-intensity equations, a sample selection model was also estimated.[10] The estimation results of the sample selection model were very close to those of the two-part model and there were no indication of correlation between the error terms. The estimated correlation was 0.2606 and the null hypothesis of zero correlation could not be rejected. As a result the two-part model was chosen.

Acceptance-decision

The estimation results in Table 6 suggest that the acceptance decision follows closely the publicly stated funding principle. Especially the stated emphasis of Tekes on funding SMEs and technologically challenging projects stands out. The marginal effects show that being a SME increases the acceptance probability by almost 20 percent on average and a one point increase in *CHALLENGE* increases the acceptance probability on average by 16 percent.

In addition the results support the aim of Tekes to encourage co-operation between different actors, and the funding principles stating that Tekes tolerates

[10]These results refer to a specification with identification only through functional form. I also estimated a specification excluding *RISK_COMPETENCE* from the subsidy-equation and the results were qualitatively the same. In that specification the correlation between the error terms was 0.3207.

Table 6: Estimation results of the two-part model

Variable	Prob(accepted)		Subsidy-intensity	
CONSTANT	**-2.3162**	Average marginal	**0.2002**	Average marginal
	(0.2814)	effects[a]	(0.0330)	effects[a]
Firm-level				
AGE	0.0023	0.0006	**0.0006**	**0.0006**
	(0.0027)	(0.0006)	(0.0003)	(0.0003)
*EMPLOYEES**	-0.0016	-0.0004	0.00006	0.00006
	(0.0018)	(0.0004)	(0.0002)	(0.0001)
*SALES_EMPL***	0.0394	0.0100	-0.00009	-0.00009
	(0.0350)	(0.0078)	(0.0002)	(0.0023)
GRANT/APPL	0.0094	0.0024	**0.0330**	**0.0311**
	(0.1117)	(0.0321)	(0.0112)	(0.0098)
SME	**0.6859**	**0.1798**	-0.0063	-0.0060
	(0.1440)	(0.0344)	(0.0130)	(0.0101)
PARENT	0.1567	0.0386	-0.0007	-0.0007
	(0.2001)	(0.0400)	(0.0170)	(0.0154)
*R&D****	-0.0045	-0.0011	0.0004	0.0004
	(0.0052)	(0.0011)	(0.0004)	(0.0004)
R&D_DUM	-0.0999	-0.0248	**-0.0432**	**-0.0412**
	(0.1245)	(0.0302)	(0.0125)	(0.0122)
*EXPORT****	0.0010	0.0003	-0.0001	-0.0001
	(0.0012)	(0.0003)	(0.00009)	(0.00009)
EXPORT_DUM	0.1016	0.0304	0.0164	0.0154
	(0.1034)	(0.0311)	(0.0105)	(0.0124)
Project-level				
CHALLENGE	**0.6323**	**0.1600**	**0.0199**	**0.0187**
	(0.0545)	(0.0112)	(0.0060)	(0.0055)
RISK_COMPETENCE	**-0.1218**	**-0.0308**	0.0084	0.0079
	(0.0597)	(0.0134)	(0.0059)	(0.0055)
RISK_ECONOMIC	**-0.1968**	**-0.0498**	**-0.0263**	**-0.0248**
	(0.0486)	(0.0124)	(0.0054)	(0.0058)
RISK_TECHNOLOGICAL	**0.1840**	**0.0466**	**0.0185**	**0.0174**
	(0.0574)	(0.0154)	(0.0057)	(0.0067)
RISK_MARKETS	0.0033	0.0008	**-0.0177**	**-0.0167**
	(0.0529)	(0.0145)	(0.0051)	(0.0055)
NOVELTY_TECH	0.1493	0.0375	**0.0291**	**0.0276**
	(0.0995)	(0.0255)	(0.0092)	(0.0085)
NOVELTY_APPL	0.0093	0.0023	0.0053	0.00497
	(0.1008)	(0.0265)	(0.0096)	(0.0106)
NOVELTY_BUSINESS	-0.1463	-0.0373	-0.0044	-0.0042
	(0.1008)	(0.0290)	(0.0098)	(0.0088)
RESEARCH_PARTNERS	**0.0838**	**0.0212**	0.0060	0.0056
	(0.0416)	(0.0105)	(0.0038)	(0.0042)
FIRM_PARTNERS	**0.0632**	**0.0160**	**0.0037**	**0.0035**
	(0.0249)	(0.0054)	(0.0022)	(0.0019)
PROJECT_SIZE	-0.00003	-0.000008	**-0.000009**	**-0.000009**
	(0.00003)	(0.000006)	(0.000002)	(0.000002)
TECH_PROGRAM	**0.1762**	**0.0447**	-0.0027	-0.0025
	(0.0906)	(0.0219)	(0.0087)	(0.0087)
EU-SUPPORT REGION	**0.2025**	**0.0498**	**0.0290**	**0.0275**
	(0.107)	(0.0248)	(0.0106)	(0.0108)
Industry-dummies	NO		YES	
Obs.	1237		903	
log-likelihood	-555		664	
T_{LR}	334		220	
Prob > $\chi 2$(df)	0.0000		0.0000	
df	23		34	
Correctly classified	81 %			

a Computed over all observations. For a dummy (D) the difference in conditinal expectation between D=1 and D = 0 is calculated. Bootstrap standard errors with 50 replications.

* Measured in 100 employees. ** Measured in 100 000 euros. *** Measured in 10 000 000 euros.

Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.

T_{LR} = likelihood-ratio test statistic, Prob = p-value , df = degrees of freedom.

technological risk, but not risk related to the resources needed to implement the project or the economic stance of the company. Risk related to the resources reserved for the project *(RISK_ COMPETENCE)* and risk related to the economic stance of the company (*RISK_ ECONOMIC*) are negatively related to the acceptance probability. A one-point increase decreases the acceptance probability by 3 and 5 percent respectively. Technological risk is in turn positively related to the acceptance probability. An additional research or firm partner increases the acceptance probability on average by 2 percent.

Applying for a technology program increases the acceptance probability by 5 percent. This suggests that it may be slightly easier to get funding through technology programs. Belonging to an EU-support region also increases the acceptance probability as expected.

Subsidy-decision

Estimation results of the subsidy-intensity equation reveal that technological challenge and risk, economic stance of the company, and collaboration with other firms continue to have a parallel role in the subsidy-decision. The effect of *CHALLENGE* is not pronounced anymore and the marginal effect of firm partners is relatively low. An additional firm partner increases the subsidy-intensity by 0.4 percent. However, the results indicate that being a SME that had a substantial effect on the acceptance probability, does not seem to matter for the subsidy-intensity. In addition, the number of research partners does not carry a statistically significant coefficient in the subsidy-intensity equation. *RISK_ COMPETENCE* seems to have an effect only at the acceptance stage. This suggests that unrealistic projects, in terms of resources reserved for the project, are sorted out.

Firm-level characteristics that seem to matter only in the subsidy-decision are the age of the firm, success rate of previous applications and previous R&D activities. Age of the firm has a statistically significant but very small positive effect on the subsidy-intensity. The underlying reason might be that compared to newly established firms, the R&D activities within well established companies are more likely to consist of also basic research. Given that in more basic research oriented R&D grants are favored over loans, this might lead to a positive correlation between age and subsidy-intensity. R&D_ *DUM* gets a negative coefficient. The subsidy-intensity is on average 4.2 percent higher for those who have not been actively engaged in R&D prior the sample period. This could be an indication of activation policies that support higher subsidies for firms not actively engaged in R&D.

The success rate of previous applications has a positive but small effect on the subsidy intensity. I also conducted estimations with both the success rate of previous applications and the number of previous applications as explanatory variables. The qualitative results for the success rate remained the same and the number of previous applications was never significant in the regressions. This indicates that it is really a matter of having successful applications, not a matter of having applied. This may indicate that there is favorable learning in one or both sides that increases the future subsidy level. However, it may also be that the success rate of previous applications captures the effect of some unobserved factors on the subsidy-intensity - e.g. some characteristics related to the quality of the applicant's R&D activities not reflected in the project-level characteristics.

There are also three project level regressors that seem to determine the subsidy-intensity, but have no effect on the acceptance probability. Risk related to the perceived market opportunities (*RISK_ MARKET)* has a negative effect on the subsidy-intensity. This implies that the more uncertain the commercial potential related to the project is, the lower is the subsidy-intensity.

The technological novelty *(NOVELTY_ TECH)* in turn is positively related to the subsidy-intensity. If the technology to be developed is completely new to the firm, the subsidy-intensity is on average 2.8 percent higher. A reason may be that projects consisting of the development of technologies new to the firm are closer to basic research activities than product development activities. Tekes decides on the appropriate instruments on the basis of "market distance" so that the share of loan is the larger, the closer the outcome of the project is to a product that can be introduced in the market. Therefore pure grants are favored for more basic research oriented activity possibly leading to positive correlation between the subsidy-intensity and *NOVELTY_ TECH.*[11]

Finally, the size of the project, measured as the investments proposed by the applicant, has a negative but very small effect on the subsidy-intensity. A 100 000 euros increase in the proposed investments decreases the subsidy intensity on average by 0.9 percent. Belonging to an EU-support region is again positively

[11] It is worth stressing here that a lower subsidy-intensity does not necessarily mean less funding. It may also be an indication of loan-based funding that has a lower subsidy-intensity than funding consisting of a pure grant. In the sample 57 % of positive funding decisions consist of only a grant, 29 % consist of a combination of a grant and a loan , and 14 percent consist of only a loan.

related to the subsidy-intensity as expected.

Consistency of the decision-making with the stated policy

All in all the results suggests that by and large the actual decision-making of Tekes follows closely the publicly stated objectives and funding principles. The funding is directed to technologically demanding projects with emphasis on encouraging co-operation between different actors. Moreover, SMEs are favored over larger firms. However, being a SME and the degree of collaboration seem to determine whether the application is accepted rather than the level of subsidy-intensity.[12] In line with the funding principles Tekes tries to avoid risks related to the resources reserved for the projects and to the economic stance of the company. The latter has an effect both on the acceptance- and the subsidy-decision, while the former reduces only the acceptance probability.

There is one observation that is somewhat in contradiction with the stated objectives of Tekes: the risk related to the market potential of project proposals does not seem to matter for the acceptance decision and is negatively related to the subsidy-intensity. One might argue that if the objective is to support the creation of *challenging and innovative projects, some of which will hopefully lead to global success stories,* uncertainty related to the market outcomes cannot be avoided.

Subsidy-intensity without pure loans

To get an idea of how adding up grants and loans in the form of subsidy-intensity may affect the result, I estimated the two-part model only for grants. In the acceptance equation only applications consisting of grant were included in the estimations and in the subsidy equation only positive grant decisions were included. In the sample in question 97 percent of the applications involved a grant, and of the positive funding decisions 86 percent consisted at least a grant. The estimation results are presented in Table 7.

The first column of Table 7 indicates that for the acceptance decision, the results are very close to those applying to the whole sample. This is not surprising given that 97 percent of applications involved a grant. The results of the subsidy-decision differ somewhat more from the estimation results using the

[12]It is worth noting here that 95 % of applications in the sample consist of collaboration with firms and 72 % of collaboration with research partners. So the issue is not that much about collaborating or not but about the degree of collaboration.

Table 7: Estimation results of the two-part model for grants only

Variable	Prob(accepted), only grant applications	Grant-percentage
CONSTANT	**-2.3900** (0.2869)	**0.1035** (0.0027)
Firm-level		
AGE	0.0025 (0.0027)	**0.0006** (0.0002)
*EMPLOYEES**	-0.0016 (0.0018)	0.00003 (0.0001)
*SALES_EMPL***	0.0405 (0.0354)	-0.0002 (0.0002)
GRANT/APPL	0.0528 (0.1135)	**0.0197** (0.0105)
SME	**0.6928** (0.1448)	0.0044 (0.0116)
PARENT	0.1602 (0.2006)	-0.0104 (0.0148)
*R&D****	-0.0046 (0.0052)	0.00001 (0.0004)
R&D_DUM	-0.0677 (0.1270)	**-0.0295** (0.0116)
*EXPORT****	0.0010 (0.0012)	-0.000003 (0.00008)
EXPORT_DUM	0.0928 (0.1053)	-0.0144 (0.0098)
Project-level		
CHALLENGE	**0.6324** (0.0555)	**0.0248** (0.0055)
RISK_COMPETENCE	**-0.1205** (0.0609)	0.0045 (0.0054)
RISK_ECONOMIC	**-0.1989** (0.0494)	**-0.0149** (0.0049)
RISK_TECHNOLOGICAL	**0.1745** (0.0588)	**0.0156** (0.0053)
RISK_MARKETS	0.0223 (0.0536)	**-0.0178** (0.0047)
NOVELTY_TECH	**0.1401** (0.1011)	**0.0220** (0.0084)
NOVELTY_APPL	0.0201 (0.1026)	0.0026 (0.0087)
NOVELTY_BUSINESS	-0.1712 (0.1027)	-0.0029 (0.0090)
RESEARCH_PARTNERS	**0.0762** (0.0422)	0.0040 (0.0034)
FIRM_PARTNERS	**0.0660** (0.0253)	0.0006 (0.0020)
PROJECT_SIZE	-0.00003 (0.00003)	**-0.000009** (0.000002)
TECH_PROGRAM	**0.1816** (0.0919)	-0.0104 (0.0081)
EU-SUPPORT REGION	**0.2453** (0.1101)	**0.0181** (0.0098)
Industry-dummies	NO	YES
Obs.	1198	773
log-likelihood	-534	648
T_{LR}	318	164
Prob > χ2(df)	0.0000	0.0000
df	23	34
Correctly classified	81 %	

* Measured in 100 employees. ** Measured in 100 000 €. *** Measured in 10 000 000 €.
Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.
T_{LR} = likelihood-ratio test statistic, Prob = p-value , df = degrees of freedom.

subsidy-intensity covering all the three instruments. Qualitatively the results remain the same, but in general, the estimated coefficients tend to be slightly smaller when only grants are taken into account. However, the results are so close to each other that dropping loans from the analysis is not considered warranted.

7.3 Two-part model with decision-maker interactions

In order to analyze the consistency of decision-making within Tekes, interactions with decision-makers were added to the two-part model.[13] Table 8 presents the estimation results of the acceptance equation with interactions and Table 9 of the subsidy-decision equation with interactions. Before looking closer at the results, it is worth noting that one should not pay too much attention to the standard errors and statistical significance presented for the decision-making level of the director general and the board (*DIR_ BOARD*). There are relatively few applications treated at this decision-making level compared to the other two, and as a result multicollinearity may inflate the standard errors.

Interactions in the acceptance-equation

The first thing is to look at the behavior of the regressors that were statistically significant in the more parsimonious specification presented in Table 6 across different decision-making levels. In the acceptance equation these regressors are *SME, CHALLENGE, RISK_ COMPETENCE, RISK_ ECONOMIC, RISK_ TECHNOLOGICAL, RESEARCH_ PARTNERS, FIRM_ PARTNERS, TECH_ PROGRAM* and *EU_ SUPPORT REGION.*

According to the results the decision-making at each level appears to be relatively consistent in terms of these "common" characteristics. There are two main differences between the decision-making levels. First, both *RISK_ COMPETENCE* and *RISK_ ECONOMIC* weight the more in the acceptance decision the higher is the decision-making level. This suggests that the larger the project proposals are, the more carefully Tekes attempts to sort out projects that have no realistic premise to succeed. Second, the number of research partners does not

[13]The decision-making level of the technology field (*TECH_ FIELD*) is the reference group and interactions of the two other decision-making levels with all the regressors except the industry dummies were added. The two other decision-making levels are that of the process (*PROCESS*) and of the highest decision-making level (*DIR_ BOARD*). The highest decision-making level covers decisions done both by the board and the director general since the number of applications treated by the board and by the director general are small.

Table 8: Estimation results of the acceptance equation with decision-maker interactions

Variable	Prob(accepted) with decision-maker interactions Coeff. for TECH_FIELD	 Coeff. for PROCESS	 Coeff. for DIR_BOARD
CONSTANT	**-2.6218**	**-2.748**	**-2.6825**
	(0.4230)	(0.5100)	(0.9249)
Firm-level			
AGE	0.0038	0.0024	-0.0047
	(0.0039)	(0.0053)	(0.0085)
*EMPLOYEES**	**-0.0073**	0.0012	-0.0008
	(0.0042)	(0.0036)	(0.0043)
*SALES_EMPL***	0.0195	0.0982	0.0026
	(0.0593)	(0.0604)	(0.0099)
GRANT/APPL	0.0502	0.0315	0.4551
	(0.1693)	(0.1928)	(0.3426)
SME	**0.7233**	**0.9457**	0.4051
	(0.2262)	(0.2646)	(0.3673)
PARENT	0.5176	-0.0572	-0.1363
	(0.3734)	(0.3441)	(0.4716)
*R&D****	-0.0045	-0.0111	0.0110
	(0.0094)	(0.0121)	(0.0120)
R&D_DUM	-0.1473	-0.0622	-0.4307
	(0.1783)	(0.2177)	(0.4774)
*EXPORT****	0.0034	0.0010	-0.0018
	(0.0022)	(0.0031)	(0.0029)
EXPORT_DUM	**-0.1248**	0.2073	0.0194
	(0.1536)	(0.1803)	(0.3355)
Project-level			
CHALLENGE	**0.6176**	**0.6808**	**0.7419**
	(0.086)	(0.0952)	(0.1763)
RISK_COMPETENCE	-0.0912	-0.1698	-0.2590
	(0.086)	(0.1061)	(0.1724)
RISK_ECONOMIC	**-0.0715**	**-0.2373**	**-0.5686**
	(0.0715)	(0.0857)	(0.1641)
RISK_TECHNOLOGICAL	**0.2599**	0.1379	**0.2934**
	(0.0915)	(0.1002)	(0.1719)
RISK_MARKETS	-0.1116	0.0429	0.0424
	(0.0798)	(0.0961)	(0.1523)
NOVELTY_TECH	-0.0074	0.1858	**0.8429**
	(0.1515)	(0.1772)	(0.2866)
NOVELTY_APPL	0.1520	-0.1034	-0.1092
	(0.1469)	(0.1898)	(0.2969)
NOVELTY_BUSINESS	**-0.2923**	0.0909	-0.1212
	(0.1505)	(0.1843)	(0.2954)
RESEARCH_PARTNERS	**0.1568**	**0.1527**	-0.0044
	(0.0746)	(0.0776)	(0.0815)
FIRM_PARTNERS	0.0298	0.0383	**0.1686**
	(0.0395)	(0.0460)	(0.0664)
PROJECT_SIZE	**0.0024**	**0.0002**	0.00002
	(0.0006)	(0.0001)	(0.00004)
TECH_PROGRAM	**0.3348**	0.0680	-0.1583
	(0.1405)	(0.1550)	(0.2571)
EU-SUPPORT REGION	0.0322	**0.3660**	-0.1310
	(0.1557)	(0.1841)	(0.4076)
Obs.		1237	
log-likelihood		503	
T_{LR}		436	
Prob > $\chi 2$(df)		0.0000	
df		71	
Correctly classified		83 %	

*Measured in 100 employees. **Measured in 100 000 €. ***Measured in 10 000 000 €.

Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.

T_{LR} = likelihood-ratio test statistic, Prob = p-value , df = degrees of freedom.

seem to matter for the acceptance decision at the highest decision-making level, whereas the number of firm partners has a pronounced effect compared to other decision-making levels. One explanation underlying this result may be that the largest project proposals treated at the highest decision-making level are likely to be projects of large corporations, in which Tekes puts special emphasis on the spillover effect to the rest of the business sector. In the two lower decision-making levels the importance of research partners in turn may indicate that there the emphasis is on knowledge transfer from research to business.

In addition to the above "common" characteristics there are two additional differences across different decision-making levels. First, the technological novelty stands out in the highest decision-making level. Projects consisting of development of technologies new to the applicant have on average higher acceptance probability at the highest decision-making level compared to qualitatively no effect at the other decision-making levels. This suggests that the technological novelty of the project proposal weights more in the acceptance decision of the board and the director general compared to the other two decision-making levels. The second difference is that the number of employees gets a negative coefficient at the decision-making level of the technology field. This observation is likely to reflect that the firm groups underlying each decision-making level are somewhat different, rather than actual differences in the decision-making. Finally applying for a technology program increases the acceptance probability at the decision-making level of the technology field, while having no statistically significant effect at the other two decision-making levels. This may be an applicant driven result rather than reflecting differences in the decision-making. Given that the decision-making level of the technology field handles the smallest projects, it may be that variation in the project type or quality is larger compared to other decision-making levels and the fact that an applicant is applying for a technology program (and is thus aware of a specific technology program) captures some of this unobserved heterogeneity. Application from the EU-support region has a higher probability of being accepted at the decision-making level of the process.

Interactions in the subsidy-equation

The results of the subsidy-intensity equation in Table 9 reveal that in terms of project characteristics, the decision on the subsidy is consistent across different decision-making levels. The main difference is that when deciding on the

Table 9: Estimation results of the subsidy-decision equation with decision-maker interactions

Variable	Subsidy-intensity with decision-maker interactions		
	Coeff. for TECH_FIELD	Coeff. for PROCESS	Coeff. for DIR_BOARD
CONSTANT	**0.1766** (0.0459)	**0.1453** (0.0126)	**0.1982** (0.1153)
Firm-level			
AGE	**0.0007** (0.0003)	**0.0008** (0.0004)	-0.0003 (0.0008)
*EMPLOYEES**	-0.0002 (0.0004)	0.0003 (0.0002)	0.000004 (0.0002)
*SALES_EMPL***	-0.0011 (0.0046)	-0.00003 (0.0003)	-0.0002 (0.0003)
GRANT/APPL	**0.0643** (0.0158)	0.0195 (0.0160)	0.0024 (0.0359)
SME	0.0026 (0.0207)	0.0269 (0.0194)	**-0.0518** (0.0315)
PARENT	-0.0113 (0.0282)	0.0266 (0.0237)	-0.0099 (0.0416)
*R&D****	0.0002 (0.0006)	0.0002 (0.0005)	**0.0017** (0.0009)
R&D_DUM	0.0022 (0.0168)	**-0.0882** (0.0188)	0.0040 (0.0453)
*EXPORT****	0.00003 (0.0002)	-0.00017 (0.0001)	-0.00034 (0.0002)
EXPORT_DUM	-0.0178 (0.0148)	**0.0338** (0.0154)	**0.0551** (0.0320)
Project-level			
CHALLENGE	**0.0232** (0.0089)	**0.0315** (0.0087)	0.0171 (0.0188)
RISK_COMPETENCE	0.0031 (0.0088)	0.0095 (0.0087)	0.0156 (0.0168)
RISK_ECONOMIC	**-0.0178** (0.0078)	**-0.0317** (0.0079)	-0.0216 (0.0153)
RISK_TECHNOLOGICAL	**0.0189** (0.0084)	**0.0160** (0.0082)	**0.0270** (0.0159)
RISK_MARKETS	**-0.0177** (0.0077)	**-0.0188** (0.0076)	-0.0199 (0.0135)
NOVELTY_TECH	**0.0416** (0.0141)	**0.0278** (0.0132)	0.0249 (0.0236)
NOVELTY_APPL	0.0105 (0.0137)	0.0136 (0.0149)	-0.0165 (0.0259)
NOVELTY_BUSINESS	0.0034 (0.0142)	-0.0071 (0.0144)	-0.0306 (0.0270)
RESEARCH_PARTNERS	0.0081 (0.0067)	**0.0155** (0.0054)	-0.0047 (0.0070)
FIRM_PARTNERS	0.0006 (0.0036)	**0.0061** (0.0033)	0.0033 (0.0047)
PROJECT_SIZE	**-0.00005** (0.00002)	-0.00002 (0.0000096)	**-0.000006** (0.000003)
TECH_PROGRAM	-0.0170 (0.0129)	0.0030 (0.0126)	0.0186 (0.0233)
EU-SUPPORT REGION	-0.0021 (0.0151)	**0.0604** (0.0146)	-0.0286 (0.0350)
Obs.		903	
log-likelihood		708	
T_{LR}		308	
Prob > $\chi2$(df)		0.0000	
df		82	

*Measured in 100 employees. **Measured in 100 000 €. ***Measured in 10 000 000 €.

Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.

T_{LR} = likelihood-ratio test statistic, Prob = p-value , df = degrees of freedom.

subsidy, the decision-making level of the process seems to weight the degree of collaboration more compared to others. At the firm level there is more divergence across different decision-making levels. Here it is difficult to say whether these differences reflect different emphases in the decision-making or different compositions of the firm groups underlying each decision-making level.

There may be a behavioral interpretation related to R&D_*DUM* and *EXPORT*. The negative, and relatively large coefficient of R&D_*DUM* at the decision-making level of the process might indicate that this decision-making level puts more weight on the activation aspect of R&D subsidies. Higher subsidies are granted for those that have not been actively engaged in R&D before. The positive coefficient of *EXPORT_DUM* at the two higher decision-making levels in turn might reflect that these decision-making levels tend to grant higher subsidies to those that already have experience in international markets. This interpretation would be in line with the result that risk related to market potential is adversely related to the subsidy-intensity. The intuition is that given that Tekes attempts to support the creation of "global success stories" but at the same time avoids market risk, there may be tendency to favor those that already have experience in international markets.

Belonging to the EU-support region is positively related to the subsidy-intensity at the decision-making level of the process - as was the case also in relation to the acceptance probability. This result is do to the fact that basically all the applications concerning funding from the European Regional Development Funds are treated at the decision-making level of the process.

8 Conclusions

This paper is about how government allocates R&D subsidies to the business sector. More specifically the focus is on the determinants of the decision-rule government bureaucrats use to allocate subsidies to applicants. The program under scrutiny is that of Tekes for which I have unique project-level data on everyone who applied over the period January 2000 - June 2002. The key questions posed are:

1. Which project- and firm-level characteristics determine the subsidy-decision?

2. Is the decision-making consistent within Tekes?

3. Is the decision-making in line with the publicly stated objectives and funding principles?

The results indicate that firm- and project-level characteristics have a disproportionate effect on the probability of an application to be accepted and on the granted subsidy-level. This suggests that the subsidy-decision can be considered as a two-stage decision problem. First stage consists of the acceptance decision and in the second stage the level of the subsidy is decided.

This study finds that it is considerably easier for a SME to get funding from Tekes. However, being a SME does not seem to have an effect on the level of subsidy. The technological content of the project proposal is an important determinant of both the success and the level of the subsidy. Technological challenge and - risk increase both the acceptance probability and the subsidy-level. In addition the subsidy-level is higher for projects that consist of development of technologies new to the applicant. In contrast, risks related to the implementation of the project have an adverse effect both on the acceptance probability and the subsidy-level. The higher the risk related to the resources reserved for the project the lower the acceptance probability of the project. Risk related to the economic stance of the company also reduces the acceptance probability, but it is also adversely related to the subsidy-level. The higher the subsidy, the more careful Tekes is in assessing that the project is not likely to fail because of financial problems of the firm. In addition risk related to the potential market outcome of the project are negatively related to the subsidy-level. Together these two adverse effects on the subsidy-level suggest that the higher the subsidy, the more emphasis Tekes puts on ensuring that there are no other factors apart from the technological ones that might cause a failure of the project to generate the expected returns. In sum, the above observations suggest that when Tekes is talking about encouraging and sharing risk and uncertainty, it is to a great extent a matter of technological risk and uncertainty. The extent of collaboration has a favorable effect on the subsidy-decision, but mainly through increasing the probability of being funded.

In order to analyze the consistency of the decision-making, this study examined whether there is indication of divergent behavior at different decision-making level. The results suggest two main differences in the acceptance decision. First, risks related to the implementation of the project weight the more in the acceptance decision the higher is the decision-making level. This suggests that the larger the project proposals are, the more carefully Tekes attempts to sort out projects that have no realistic premise to succeed. Second, the extent of collaboration has a disproportionate effect at different decision-making levels with lower decision-making levels emphasising the number of research partners and the highest decision-making level emphasising the number of firm partners. One explanation underlying this result may be that the largest project proposals treated at the highest decision-making level are likely to be projects of large corporations, in which Tekes puts special emphasis on the spillover effect to the rest of the business sector. In the two lower decision-making levels the importance of research partners in turn may indicate that there the emphasis is on knowledge transfer from research to business. What comes to the decision on the subsidy-level, the decision-making is very consistent in terms of project characteristics. There are some differences in how the firm-level characteristics show up in the subsidy-level decisions across decision-making levels, but it is unclear whether there is a true behavioral interpretation to these differences.

The above results indicate that by and large the actual decision-making of Tekes follows the main official objectives and funding principles. Moreover the different decision-making levels appear to adhere to the same guidelines. The only observation that may be somewhat in contradiction with the stated policy is that if anything, the risk related to the market outcome of the project is negatively related to the subsidy-decision - namely decreases the level of subsidy. Let us think for a while what a statement like *Tekes funding is intended for challenging and innovative projects, some of which will hopefully lead to global success stories* might imply. To me this sounds more like developing something new and challenging that has a potential to become a success story in the future markets rather than trying to fill in a niche in today's markets with a highly demanding innovation project. How likely is it to end up with an idea that has the potential of becoming a global success story, but incorporates little risk related to the market outcome? Given that Tekes is a government agency redistributing taxpayers' money, the risk-averse attitude in relation to market risk is understandable. However, if the goal is to generate innovations that lead to global success stories, it may be reasonable to consider whether Tekes should and could have more tolerance toward market risk-in addition to the technological one.

This study has examined whether Tekes behaves as it preaches. The answer is yes. What has not been analyzed here is should Tekes behave as it preaches. In other words, are the assumptions that underly the rationales supporting the funding policy of Tekes valid. A key theme in the funding policy is the risk and uncertainty related to innovative activities. The rationale supporting government intervention to encourage risk-taking in innovation activities relies on the assumption that firms are risk-averse in their innovation activities. An important question is whether this is true or not. I do not know the answer, but this is certainly something that should be discussed.

References

[1] Acemoglu, Daron and Thierry Verdier (2000): The Choice between Market Failures and Corruption, *The American Economic Review*, 90 194-211.

[2] Arrow, Kenneth J. (1962): Economic Welfare and the Allocation of Resources for Invention, in Nelson, R. (ed.),The Rate and Direction of Inventive Activity, Princeton University Press, Princeton.

[3] Arrow, Kenneth J. and Robert C. Lind (1970): Uncertainty and the Evaluation of Public Investment Decisions, *The American Economic* Review, 60, 364-378.

[4] Blanes, J. Vicente and Isabel Busom (2004): Who participates in R&D subsidy programs? The case of Spanish manufacturing firms, *Research Policy*, 33, 1459-1476.

[5] Downs, Anthony (1965): The Theory of Bureaucracy, *The American Economic Review*, 55, 439-446.

[6] Feldman, M. P. and M. R. Kelley (2001): Winning an award from the advanced technology program: pursuing R&D strategies in the public interest and benefiting from a Halo effect, NISTIR 6577, US Department of Commerce.

[7] Gans, Joshua S. and Scott Stern (2000): When does funding research by smaller firms bear fruit?: Evidence from the SBIR program, Economics of Innovation and New Technology, 12, 361-384.

[8] Georghiou, Luke, Keith Smith, Otto Toivanen and Pekka Ylä-Anttila (2003): Evaluation of the Finnish Innovation Support System, Ministry of Trade and Industry Publications, 5/2003.

[9] Hall, Bronwyn (2002): The Financing of Research and Development, *Oxford Review of Economic Policy*, 18, 35-51.

[10] Hall, Bronwyn and John Van Reenen (2000): How effective are fiscal incentives for R&D? A review of the evidence, *Research Policy*, 29, 449-469.

[11] Hautamäki, Antti (2001): Finland in the Face of Change. A Report on Finland's Challenges, Sitra Reports series 19. Available at http://www.sitra.fi, accessed 29/08/06.

[12] Heckman, James, Carolyn Heinrich and Jeffrey Smith (1997): Assessing the Performance of Performance Standards in Public Bureaucracies, *The American Economic Review*, 87, Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association, 389-395.

[13] Heckman, James J. and Jeffrey A. Smith (2004): The Determinants of Participation in a Social Program: Evidence from a Prototypical Job Training Program, *Journal of Labor Economics*, 22, 243-298.

[14] Heckman, James, Jeffrey A. Smith and Christopher Taber (1996): What do bureaucrats do? The effects of performance standards and bureaucratic preferences on acceptance into the JTPA program, NBER Working Paper, 5535.

[15] Leland, H. E. and D. H. Pyle (1977): Informational Asymmetries, Financial Structure, and Financial Intermediation, *The Journal of Finance*, XXXII, 371-387.

[16] Lemola, Tarmo (2002):Convergence of national science and technology policies: the case of Finland, *Research Policy*, 31, 1481-1490.

[17] Lichtenberg, Frank R. (1998): The Allocation of Publicly-Funded Biomedical Research, NBER Working Paper 6601.Lichtenberg (1998):

[18] McFadden, Daniel (1975): The Revealed Preferences of a Government Bureaucracy: Theory, *The Bell Journal of Economics*, 6, 401-416.

[19] McFadden, Daniel (1976): The Revealed Preferences of a Government Bureaucracy: Empirical Evidence, *The Bell Journal of Economics*, 7, 55-72.

[20] Myers, Stewart C. and Nicholas S. Majluf (1984): Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics*, 13, 187-221.

[21] Niskanen, William (1968): The Peculiar Economics of Bureaucracy, *The American Economic Review*, 58, 293-305.

[22] Oinas, Päivi (2005): Finland - A success story?, *European Planning Studies*, 13, 1227-1244.

[23] Schienstock, G. and Timo Hämäläinen (2001): Transformation of the Finnish innovation system: a network approach, Sitra Reports series, 7. Available at http://www.sitra.fi, accessed 29/08/06.

[24] Stiglitz, Joseph (1998): Distinguished Lecture on Economics in Government: The Private Uses of Public Interests: Incentives and Institutions, *The Journal of Economic Perspectives*, 12, 3-22.

[25] Tekes: Annual Review 2005. Available at http://www.tekes.fi/eng/publications/Annual_Review_2005.pdf, accessed 31/08/06.

[26] Thomas, Lacy Glenn (1988): Revealed bureaucratic preferences: priorities of the Consumer Product Safety Commission, *RAND Journal of Economics*, 19, 102-113.

[27] Trajtenberg, Manuel (2001): R&D Policy in Israel: An Overview and Reassessment, in Maryann P. Feldman and Albert N. Link (eds.), Innovation Policy in the Knowledge-Based Economy. Boston: Kluwer Academic Publishers, pp. 409-454.

Appendix 1

Two-limit model of subsidy-intensity with industry dummies			
CONSTANT	**-0.2687** (0.0411)	*RESEARCH_PARTNERS*	**0.0138** (0.0053)
AGE	**0.0007** (0.0003)	*FIRM_PARTNERS*	**0.0102** (0.0032)
*EMPLOYEES**	0.00002 (0.0002)	*PROJECT_SIZE*	**-0.00001** (0.000003)
*SALES_EMPL***	-0.0001 (0.0003)	*TECH_PROGRAM*	**0.0223** (0.0121)
GRANT/APPL	**0.0278** (0.0153)	*EU-SUPPORT REGION*	**0.0492** (0.0146)
SME	**0.0748** (0.0181)	*FOOD*	**0.11** (0.0384)
PARENT	0.0074 (0.0246)	*PAPER*	0.0383 (0.0393)
*R&D****	-0.0001 (0.0006)	*CHEMI*	-0.002 (0.0276)
R&D_DUM	**-0.0421** (0.0170)	*RUBBER*	0.046 (0.0301)
*EXPORT****	-0.00003 (0.0001)	*METAL*	-0.0229 (0.0276)
EXPORT_DUM	**0.0250** (0.0144)	*ELECTRIC*	0.02 (0.0249)
CHALLENGE	**0.0970** (0.0074)	*RADIOTV*	-0.0067 (0.0328)
RISK_COMPETENCE	-0.0073 (0.0080)	*OTHERMAN*	-0.0327 (0.0313)
RISK_ECONOMIC	**-0.0412** (0.0069)	*BUSINESS_S*	0.0108 (0.0225)
RISK_TECHNOLOGICAL	**0.0363** (0.0077)	*O_SERVICE*	0.0429 (0.0325)
RISK_MARKETS	-0.0111 (0.0070)	*OTHER*	**0.0549** (0.0292)
NOVELTY_TECH	**0.0401** (0.0129)		
NOVELTY_APPL	0.0052 (0.0134)		
NOVELTY_BUSINESS	**-0.0232** (0.0136)		
Obs.		1237	
log-likelihood		-73	
T_{LR}		22	
Prob > $\chi2$(df)		0.0212	
df		11	

* Measured in 100 employees. **Measured in 100 000 euros. ***Measured in 10 000 000 euros.

Note: Standard errors in parentheses. Figures in bold indicate statistical significance at least at the 10 % level.

V Adverse selection and innovation financing: Is there need for R&D subsidies?

Abstract

This paper analyzes the role of research and development (R&D) subsidies in reducing possible adverse selection based financing constraints related to innovation financing. Asymmetric information about the quality of an innovation project between the entrepreneur and the financier leads to a higher cost of external than internal capital, creating a funding gap. This funding gap may prevent especially small and new technology-based firms from undertaking economically viable innovation projects. Results indicate that under certain conditions, public R&D subsidies can reduce these financing constraints. Two different channels generate this effect. First, the subsidy itself reduces the capital costs related to the innovation projects by reducing the amount of external capital required. Second and more important, the observation that an entrepreneur has received a subsidy for an innovation project provides an informative signal to the market-based financier.

JEL classification: D82, G28, H20, O30, O38

Keywords: adverse selection, innovation financing, financial constraints, R&D subsidies, screening

1 Introduction

Previous research suggests that especially small innovative firms may face financing constraints that prevent them from undertaking profitable R&D projects. Moreover, the private sector solution to the problem, namely venture capital organizations, may fail to correct this market failure. These observations have provided grounds for government intervention aimed at reducing financing constraints. One of such policy tools is direct subsidies to corporate R&D. However, the theoretical literature linking financing constraints and R&D subsidies is sparse. This study contributes to filling this gap.

Financing constraints are to a large extent generated by asymmetric information between the entrepreneur and the financier. Two main channels through which informational asymmetries can generate financing constraints are adverse selection and moral hazard. Adverse selection is caused by ex-ante informational asymmetries between the entrepreneur and the financier and moral hazard arises from incentive problems. This paper focuses on adverse selection related financing constraints.

Leland and Pyle (1977) and Myers and Majluf (1984) are among the early contributors that applied the idea of adverse selection to financial markets. The starting point of their analysis is that the lemons problem identified by Akerlof (1970) and Spence (1973) is highly present also in the financial markets. In financial markets the lemons problem is related to asymmetric information about the quality of an investment project (or the value of a firm in general). When entrepreneurs have better information about the quality of their own projects than lenders, a lender cannot correctly asses the expected value of a project, and the lenders valuation of the project reflects average project quality. Given that the project quality varies from profitable projects to economically non-viable projects, this may raise the rate of return required by external investors so that it is not worthwhile to undertake an economically viable project. In other words if the entrepreneur had sufficient internal funding for the project she would launch the project, but if internal funding is insufficient, the higher cost of external capital prevents her from undertaking the project.

Asymmetric information may cause financing constraints both in equity and debt markets (Myers and Majluf 1984, Stiglitz and Weiss 1981). Two interrelated solutions have been proposed: signaling and financial intermediation. If entrepreneurs could credibly signal the quality of their project to financiers, the financial constraints caused by adverse selection would disappear. An entrepreneur's willingness to invest in the project or a loan contract with collateral could serve as such signals (Leland and Pyle 1977, Bester 1985, and Besanko and Thakor 1987). An appropriate reputation may also reduce informational problems (Diamond, 1989). Over time borrowers who mange to acquire good reputation face less sever informational problems.

Financial intermediation in turn could alleviate financing constraints caused by asymmetric information through information gathering. Especially the role of banks as information processing financial intermediaries has been discussed (Chan, Greenbaum and Thakor 1986 and references therein). According to this approach, banks (or other financial intermediaries) possess an information processing technology that enables them to screen loan applicants at a cost advantage relative to individual lenders. Outside corporate finance literature the role of certification by a certification intermediary has been highlighted as a solution for the problem of asymmetric information (Auriol and Schilizzi, 2003 and Albano and Lizzeri, 2001). Through information gathering the certification intermediary grants certificates, which then serve as signals of quality.

There are several arguments why the above solutions may fail to eliminate financing constraints. First, an entrepreneur may lack the means to signal project quality. Own wealth is needed to invest in the project or to provide collateral and reputation building may take time. Second, the screening activities of financial intermediaries may be inefficient. Chan, Greenbaum and Thakor (1986) argue that increased competition in banks operating environment has reduced banks' information surplus, and information reusability has declined, due to greater temporal volatility in borrower credit risks. Together these two factors have reduced banks screening activities. In addition the threat of expropriation may undermine screening activities (Bhattacharya and Ritter, 1983 and Ueda, 2004). An entrepreneur looking for external financing has valuable private information about her project. When revealing some of this information to a financial intermediary in order to get funding, there is a risk that the intermediary steels the information. This threat of expropriation is especially relevant in R&D.

Given that informational problems are assumed to be particularly important in R&D (Hubbard, 1998, Alam and Walton, 1995), the above discussion suggests that if adverse selection related financing constraints exist, it is especially innovative small firms that may face them. Large, well-established firms are in a better position to cope with financing constraints. They are likelier to have enough internal funding and even if they need external funding, they often have better means to credibly signal the project quality to external financiers (for example with collateral or by investing own wealth in the project). Moreover a well-established firm is likely to have acquired a reputation that helps in seeking external financing. Small innovative firms often lack internal funding and means to credibly signal the project quality. If, in addition, the screening activities of financial intermediaries are inefficient as proposed above, financing constraints prevents innovative small firms from undertaking profitable R&D projects.

A branch of empirical studies has analyzed whether R&D investment is sensitive to cash flow. The underlying idea is that due to adverse selection internal funding is favored in R&D and if this holds, R&D investment reacts to cash flow. Sensitiveness to cash flow is interpreted as an indication of financing constraints. In relation to the topic of this paper the main conclusion is that financing constraints may hinder R&D activities, at least in the case of newly established, small, technology-based firms (e.g. Hall 1992, Hao and Jaffe 1993 , Himmelberg and Petersen 1994, Bond, Harhoff and Van Reenen 2003, Bougheas, Görg and Strobl 2001). Recent Finnish evidence points that newly established technology-based small and medium size firms may suffer from financial constraints (Hyytinen et al., 2002).[1]

Venture capital organizations have been provided as a special form of financial intermediation to alleviate capital constraints facing innovative small firms. It has been argued that through intensive ex-ante screening and active monitoring, venture capitalists can overcome informational and incentive problems and reduce capital constraints (Lerner, 1998). However, Hall (2002) and Lerner (1998, 2002) point that even VC may fail in this respect. First, a modest number of firms receive VC each year and VC tends to be highly concentrated in specific sectors. Second, VC investments tend to be too large for small innovative firms in some sectors. Third, a well functioning VC market requires a well functioning small and new firm stock market enabling viable exits from VC investments. The last argument is especially relevant for many small European countries, like Finland, in which the exit opportunities for VC investors are limited. Moreover, Amit, Brander and Zott (1998) add that the areas in which venture capitalists focus are those characterized by significant information asymmetry, and venture capital organizations are likely to favor firms with some track records over pure

[1]There is also contradictory evidence. For example Blass and Yosha (2003) do not find evidence of financing constraints when studying publicly traded R&D-intensive manufacturing firms in Israel. However, publicly traded firms can be considered as well-established firms and at least the theoretical considerations point that these firms are less likely to suffer from financing constraints.

start-ups.

The above considerations have provided grounds for government intervention aimed at reducing financing constraints. One of such policy tools is direct subsidies to corporate R&D. Government programs allocating direct subsidies are based on a specific selection scheme. Projects and entrepreneurs that receive a subsidy must fulfill some predefined criteria in order to be funded. This selection is done by ex-ante screening of the applications. The paper develops a model of asymmetric information and adverse selection in order to analyze whether R&D subsidy policies can reduce adverse selection based financing constraints. Results indicate that under certain circumstances R&D subsidies can do that. The effect comes through two channels. First, the subsidy itself reduces the capital costs related to the innovation projects by reducing the amount of external market-based funding needed. Second, the observation that an entrepreneur has received a subsidy for an innovation project provides an informative signal to the market-based financier.

The modeling framework adopted in this paper builds on the seminal model of Holmström and Tirole (1997). Other similar modeling approaches can be found in Repullo and Suarez (2000) and Da Rin, Nicodano and Sembanelli (2005). However, this paper differs from the above three in that instead of moral hazard the focus is on adverse selection. Whereas the above three papers highlight the role of monitoring in reducing financing constraints, this paper focuses on ex-ante informational asymmetries and the role of screening and signaling in reducing financing constraints. The agents in the model are entrepreneurs, uninformed market-based financiers and a government agency allocating R&D subsidies. Holmström and Tirole (1997) and Repullo and Suarez (2000) identify informed financial intermediaries with banks and Da Rin, Nicodano and Sembanelli (2005) with venture capital firms. The starting point in this paper is that banks are not informed enough and venture capital markets do not function well enough to eliminate financing constraints facing small innovative firms. The point is to analyze whether R&D subsidies could improve the situation and under which circumstances.

Despite the fact that R&D subsidies constitute a widely used technology policy tool, the theoretical literature examining R&D subsidies is rather limited. The majority of earlier studies arise from the view that government intervention in R&D is needed because social benefits of R&D are higher than their private returns. Subsidies and their allocation are taken as given and the focus is on analyzing how R&D subsidies affect firm behavior. Stenbacka and Tombak (1998) study how R&D subsidies affect investment incentives of firms. Da Rin, Nicodano and Sembenelli build on the financing constraint argument, but instead of analyzing direct R&D subsidies they analyze governments role in supporting the development of active venture capital markets. Lerner (1998, 2002) provides a discussion on the rationales for government policies to encourage angel investors and on public venture capital programs.

The design and the institutional setting of the R&D subsidy program modeled in this paper are linked to the R&D subsidy program of the National Funding Agency for Technology and Innovation (Tekes) in Finland. Tekes is the principal public promoter of private R&D in Finland and also the most important public financier of business R&D (for more details see e.g. Georghiu et al., 2003).

Section 2 identifies the funding gap by analyzing entrepreneurs' possibilities to fund their innovation projects, in the absence of subsidies. Section 3 presents a dynamic game of incomplete information describing the subsidy applications process. The section concludes with the equilibrium strategies of both the public agency and the entrepreneurs. Section 4 links external market-based financiers and subsidies to analyze the effects of subsidies on the funding gap. Section 5 concludes the paper.

2 Identifying the funding gap

This section analyzes which entrepreneurs are likely to face financing constraints that prevent them from undertaking economically viable innovation projects in the absence of public R&D subsidies. This is done by modifying the setup of the moral hazard model of financial intermediation by Holmström and Tirole (1997), into an adverse selection framework. Given the focus of this paper on pre-project selection process and its implications on innovation financing, the adverse selection framework is more appropriate than the moral hazard one.[2] At this stage, the actors in the model are entrepreneurs and uninformed market-based financiers. Entrepreneurs can get financing only from market-based financiers. Both the entrepreneurs and financiers are risk neutral and competitive financial markets are assumed.

[2]Moreover, the moral hazard problem related to the implementation of an innovation project is at least in the Finnish subsidy system to some extent reduced by several factors. First, the subsidy is paid only against realized costs; second, the public financier requires quite extensive reporting all along the innovation project; third, a significant number of subsidized R&D projects is annually randomly audited. According to Tekes, misuses are rare.

Each entrepreneur has one innovation project. The quality of this R&D project is exogenously given, and it is determined by the type of the entrepreneur. The type of the entrepreneur can be either high (H) or low (L). The entrepreneur knows its type. Let λ_i and R_i denote the success probability and the financial return on a successful project with type i. In the case of failure, both projects yield 0. Assume that $\lambda_H > \lambda_L$, $R_L > R_H$, $\lambda_H R_H > \lambda_L R_L$.[3] One can think of low-type projects as extremely risky or unrealistic projects. If a low-type project succeeds, it generates a high financial return, but the risk related to the project is unbearable. The size of investment needed for both types of projects is I.

Entrepreneurs differ in the amount of initial capital A they possess. A is distributed across entrepreneurs according to a cumulative distribution function *G(A)*, and it is independent of the type of the entrepreneur. We assume that no entrepreneur has more than I of initial wealth A, so *G(A)* is defined on interval $[0, I]$. For simplicity, the exogenous rate of return on investor capital is assumed to be equal to one. We also assume that $\lambda_H R_H - I > 0 > \lambda_L R_L - I$. In other words, only high-type projects generate financial profit, whereas low-type projects are not economically viable. Low-type projects could be characterized as overly risky or 'absurd' innovation projects. If successful, a low-type project is like a jackpot generating an enormous financial return, but the possibility of success is negligible.

Market-based financiers cannot by themselves assess the quality of the project. All the financiers know is that the share of high-type projects in the population is p. Assume that once the project is finished, the success of the project is verifiable. If the project has succeeded, then the entrepreneur and the financier split the return of a project of type i so that $R_i = R_i^E + R_i^F$. R_i^E is the entrepreneur's share of the financial return and R_i^F is the financier's share.

An entrepreneur is willing to launch the project if her expected profit from the project is at least as much as the entrepreneur would get from investing the initial capital to alternative sources, i.e. the market value of initial capital. Since the exogenous rate of return on investor capital is assumed to be equal to one, the market value is A. The entrepreneur's participation constraint reads as $\lambda_i R_i^E \geq A$. Thus, the pledgeable income that can be offered to the financier is given by $R_i^F = R_i - R_i^E = R_i - \frac{A}{\lambda_i}$. For the financier to be willing to invest in a project, her expected income from investing in a project should be at least as

[3] In other words, second order stochastic dominance (but not mean preserving spread) characterizes this set up.

much as the market value of the funds supplied, *I-A*.

In the following, I study how the composition of entrepreneurs that get market-based financing depends on the amount of initial capital entrepreneurs possess. The share of financial return an entrepreneur promises to the financier if the project succeeds,R_i^F, serves as a signal of her quality to the financier. Entrepreneurs differ in the amount of initial capital they possess, and depending on the value of initial capital this signal can be either truth-revealing or not. I first identify the region of initial capital in which high-type entrepreneurs have no means to credibly signal their quality. Then I analyze, which entrepreneurs, with initial capital belonging to this region, can get market-based financing. Second, I focus on the region of initial capital in which high-type entrepreneurs could credibly signal their quality, if they had an incentive to do so, and analyze the composition of entrepreneurs financed within this region.

Let us first analyze the case in which low-type entrepreneurs can always pretend to be high-type entrepreneurs. This happens when low-type entrepreneurs can offer the financier at least as much as high-type entrepreneurs, i.e. when $R_L^F \geq R_H^F$. Solving this inequality for A gives

$$A \leq \hat{A} \equiv \frac{\lambda_L \lambda_H \Delta R}{\Delta \lambda} \tag{1}$$

where $\Delta\lambda = \lambda_H - \lambda_L$ and $\Delta R = R_L - R_H$. When the initial wealth is less than $\hat{A}$, the maximum amount of financial return a high-type entrepreneur is willing to promise to the financier if the project succeeds is never higher than what a low-type entrepreneur could promise. This means that when the initial wealth is less than $\hat{A}$, a high-type entrepreneur has no means to truthfully signal her quality even if she had an incentive to do so. When (1) holds, low-type entrepreneurs could offer the financier a larger return of a successful project, but since it is not in the interest of a low-type entrepreneur to reveal its type, both high and low-type entrepreneurs offer the same amount to the financier.

Financier's participation constraint determines which entrepreneurs get financing. Competitive financial markets are assumed, so the minimum amount F that the financier requires in order to invest in a project with expected success probability $\bar{\lambda}$ is

$$F = \frac{I - A}{\bar{\lambda}} \tag{2}$$

where $\bar{\lambda} = p\lambda_H + (1-p)\lambda_L$. The maximum amount that a high-type entrepreneur is willing to offer to the financier is the pledgeable income $R_H^F = R_H - \frac{A}{\lambda_H}$. As a result, projects can get market-based funding as long as

$$\frac{I - A}{\bar{\lambda}} \leq R_H - \frac{A}{\lambda_H}. \tag{3}$$

(3) is the financier's participation constraint when $A \leq \hat{A}$. The left hand side of equation (3) is the minimum amount that the financier requires in order to invest in a project, and the right hand side is the maximum share of a successful project an entrepreneur is willing to promise to the financier. A low-type entrepreneur could offer the financier more, but it is not in the interest of a low-type to reveal her type. Solving (3) for A gives us

$$A \geq \bar{A} \equiv \frac{\lambda_H}{\lambda_H - \bar{\lambda}}(I - \lambda \bar{R}_H). \tag{4}$$

$\bar{A}$ is the threshold value of initial capital needed to get financing, when the financier anticipates all the entrepreneurs to seek financing. Entrepreneurs with less initial capital than $\bar{A}$ cannot get market-based financing for their project.

When $R_L^F = R_H^F$, that is when $A \geq \hat{A}$, a high-type entrepreneur could truthfully signal her quality, but it is not necessarily in her interest to do so. Given the assumption of competitive financial markets, the minimum amount that a financier requires in order to invest in a project of unknown quality continues to be F , as long as also low-type entrepreneurs can afford offering F to the financier. This happens when

$$\frac{I - A}{\bar{\lambda}} \leq R_L - \frac{A}{\lambda_L}. \tag{5}$$

The left-hand side of equation (5) is the minimum amount the financier requires in order to invest in a project of unknown quality and the right-hand side is the maximum amount a low-type entrepreneur is willing to promise to the financier, if the project succeeds. Solving (5) for A gives us

$$A \leq \dot{A} \equiv \frac{\lambda_L}{p\Delta\lambda}(\bar{\lambda} R_L - I). \tag{6}$$

A high-type entrepreneur has no incentive to separate herself from a low-type, since in order to separate, she should offer more than F to the financier, but only F is needed to ensure funding.

When $A \geq \dot{A}$ a low-type entrepreneur can no longer offer F to a financier. However, there is an interval from $\dot{A}$ to $\ddot{A}$, in which the financier cannot be sure that an entrepreneur offering $\frac{I-A}{\lambda_H}$ is of a high-type. If the financier knew that the entrepreneur is of a high-type, $\frac{I-A}{\lambda_H}$ would be enough for the financier to be willing to invest in a project. However $\lambda_H > \bar{\lambda}$ and a low-type entrepreneur can offer the financier $\frac{I-A}{\lambda_H}$ for some values of A greater than $\dot{A}$. Solving the inequality $\frac{I-A}{\lambda_H} \leq R_L - \frac{A}{\lambda_L}$ for A gives $\ddot{A}$. If

$$\dot{A} \leq A \leq \frac{\lambda_L}{\Delta\lambda}(\lambda_H R_L - I) = \ddot{A}, \tag{7}$$

a low-type entrepreneur can pretend to be of high-type by offering $\frac{I-A}{\lambda_H}$ to the financier. Therefore, when $\dot{A} \leq A \leq \ddot{A}$, there is a semi-separating equilibrium in which all the high-type entrepreneurs and a share of low-type entrepreneurs are funded. In other words, only a share of low-type entrepreneurs applies for funding. When $A \geq \ddot{A}$, the financier knows that only high-type entrepreneurs are willing to offer $\frac{I-A}{\lambda_H}$.

Figure 1 summarizes different funding regions for different values of initial capital. Given that $\bar{A}$ and $\dot{A}$ depend on the share of high-type entrepreneurs in the population (p), the different regions are presented with coordinates (p, A), $p \in [0,1]$. When $A \leq min\{\hat{A}, \bar{A}\}$, market based financiers are not willing to fund any project. Note that for this region, the upper bound of p is $\frac{I-\lambda_L R_H}{\Delta R_H}$. When , $\bar{A} < A \leq \dot{A}$ the financier is offered $F = \frac{I-A}{\bar{\lambda}}$, and both types of entrepreneurs are funded. When ,$\hat{A} < A$, $\dot{A} < A$, and $A < \ddot{A}$, all the high-type entrepreneurs and a share of low-type entrepreneurs are funded. When $A \geq \ddot{A}$, only high-type entrepreneurs are funded.

Proposition 1 *In a population where the share of high-type entrepreneurs p fulfills* $p \leq \frac{I-\lambda_L R_H}{\Delta\lambda R_H}$*, high-type entrepreneurs with* $A \leq min\{\hat{A}, \bar{A}\}$ *suffer from the funding gap that prevents them from undertaking economically viable innovation projects.*

Proposition 1 identifies the funding gap. Financial constraints prevent high-type entrepreneurs with $A \leq min\{\hat{A}, \bar{A}\}$ from undertaking economically viable innovation projects. This means that asymmetric information causes financial constraints only if entrepreneurs do not have sufficient internal capital to invest in an innovation project. In the following, the analysis is restricted to the funding gap region i.e. to entrepreneurs that have $A \leq min\{\hat{A}, \bar{A}\}$. The intuition is that these entrepreneurs do not have enough wealth to internally fund the project or credibly signal the quality of the project to the financier.

In order to analyze the outcome in different regions presented in Figure

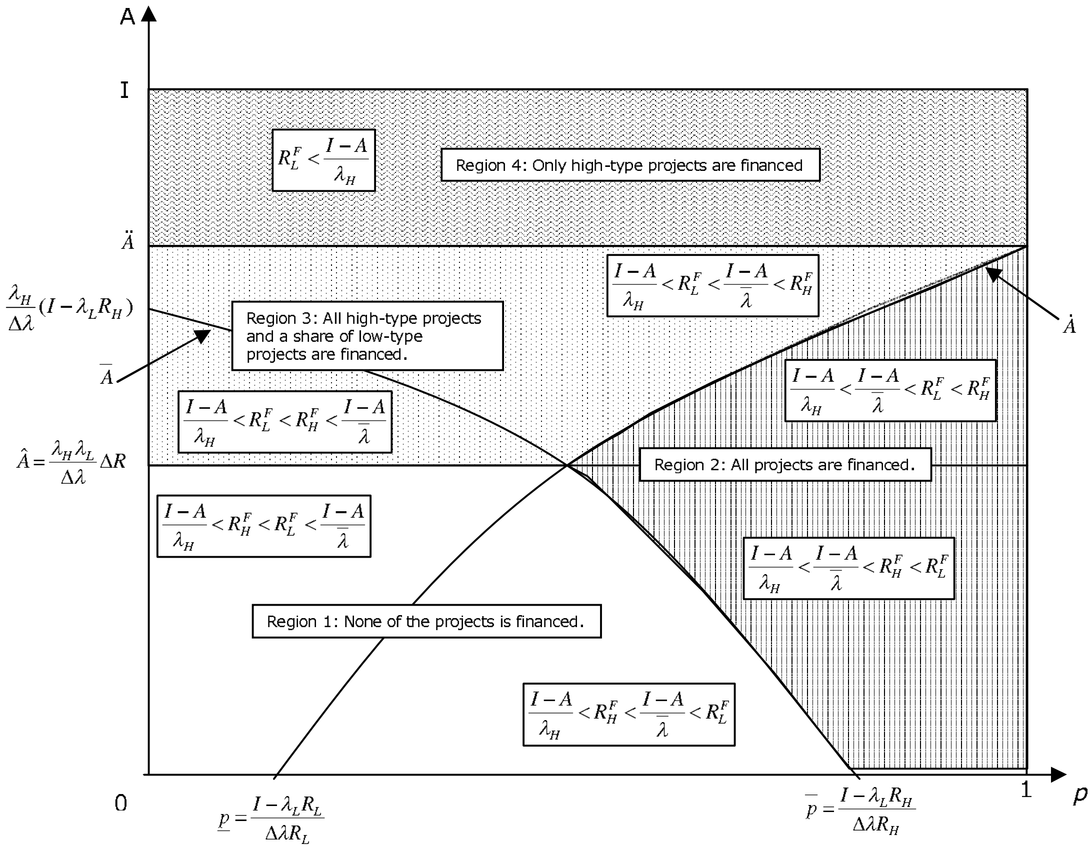

Figure 1: Market-based financing with different values of initial capital

1 from a social point of view, I compare the outcome in each region to the full information outcome. In the full information case, all the high-type entrepreneurs get market-based financing, and the share of a successful project given to the financier is $\frac{I-A}{\lambda_H}$. Low-type entrepreneurs are not financed. The region 4 where $A \geq \ddot{A}$ corresponds to the full information outcome. Only high-type entrepreneurs are financed, and the financier gets $\frac{I-A}{\lambda_H}$, if the project succeeds. Clearly this is the socially optimal situation.

In region 2 ($\bar{A} \leq A \leq \dot{A}$) and in region 3 ($\hat{A} \leq A, \dot{A} \leq A$ and $A \leq \ddot{A}$) all the high-type entrepreneurs are financed. There is no social inefficiency related to the financing of high-type entrepreneurs, but also low-type entrepreneurs are financed, which creates a social loss. In the full information case no low-type entrepreneurs are financed. In the asymmetric information case, all the low-type entrepreneurs in region 2 and some low-type entrepreneurs in region 3 get financing for their projects. In other words, there is excessive financing in regions 2 and 3 as in de Meza and Webb (1987). This is socially costly. In terms of high-type entrepreneurs, the difference compared to the full information case is that the financial return of a successful project is differently divided between the entrepreneur and the financier. In the full information case, the high-type entrepreneur gets a larger share than in the asymmetric information case.

In region 1 ($A \leq min\{\hat{A}, \bar{A}\}$) no entrepreneur is financed. From the social point of view it is efficient that low-type entrepreneurs do not get financing. High-type entrepreneurs should, however, get financing for their projects as in the full information case. Financial constraints that prevent high-type entrepreneurs in region 1 from undertaking R&D-projects, create a social loss. Since this paper is about financing constraints, I focus in the following on region 1 where financial constraints are present.

3 R&D subsidy application process

This section develops a dynamic game with incomplete information describing the R&D subsidy application process. The final goal is to analyze the interplay of R&D subsidies and market-based financing. In this final setup entrepreneurs can first apply for an R&D subsidy and then seek market-based financing. Before doing this, I first describe and analyze the subsidy application process. This is done by constructing a game between entrepreneurs and a public financier providing R&D subsidies. Entrepreneurs with R&D projects are characterized as in the previous section. The public financier is called Government in the following. Like entrepreneurs also Government is risk neutral. An entrepreneur has to decide whether to apply for an R&D subsidy or not. If the entrepreneur decides to apply, it incurs an application cost (c).

Government does not observe the type of the entrepreneur. All it observes is whether the entrepreneur sends an application or not. Government can learn the type of the entrepreneur by screening the application. However, the screening is costly. I assume that there is a screening cost (σ) related to screening. The screening is perfect, i.e. by screening Government can verify the entrepreneur's true type.

There is a fixed subsidy (S) that is granted to an accepted application. Tax funds are used to finance subsidies. The opportunity cost of tax funds is $1+g$ ($0< g <1$). If successful, a project of a high-type entrepreneur generates a social benefit W_H to Government with probability λ_H and a project of a low-type entrepreneur generates no social benefit to Government, that is $W_L = 0$. Note that financial return R_i is not included in the social benefit. Social benefit covers the additional social welfare generated by the project including e.g. the effects of spillovers and consumer surplus. The timing of the game is as follows:

1. Nature draws a type (t) for the entrepreneur. The type can be either high (H) or low (L), $i \in T=\{H, L\}$. T is the type space. Probabilities of a high type and a low type are p and (1-p) respectively, $0 < p < 1$.

2. The entrepreneur observes her type and then chooses whether to apply (AP) for an R&D subsidy or not (NAP), $A^F= \{AP, NAP\}$ is the action space of the entrepreneur. If the entrepreneur sends an application she incurs a fixed application cost c. If the entrepreneur decides not to send an application the game ends with a net payoff of zero to both the entrepreneur and Government.

3. Government receives the application, but does not observe the type of the entrepreneur. It has to decide whether to screen (SC) the application or not (NSC). If Government screens the application, it incurs a screening cost σ, but finds out the true type of the entrepreneur. At this stage the action space of the Government is $A_1^G= \{SC, NSC\}$.

4. Government has to decide whether to give the entrepreneur a fixed subsidy of S or not. The action space of Government is $A_2^G= \{S, NS\}$. If Government has chosen SC in the previous phase, it observes the true

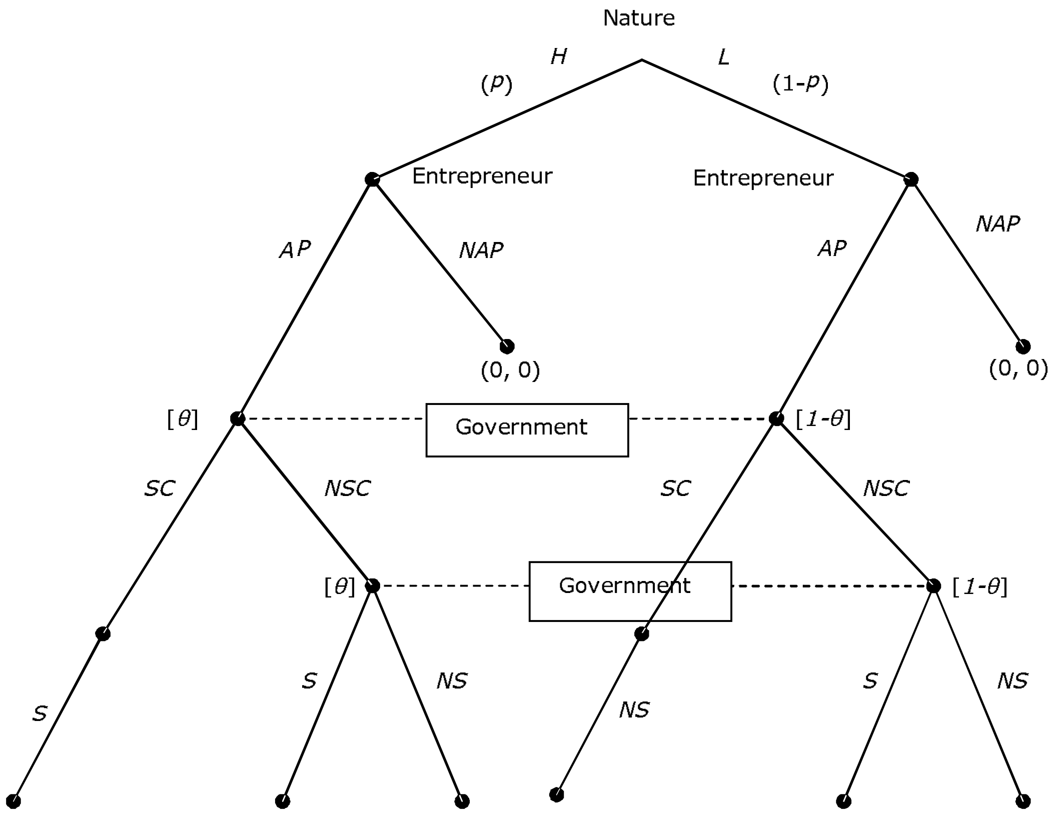

Figure 2: Extensive-form representation of the application process with perfect screening

type of the entrepreneur by screening, and grants a subsidy to a high-type entrepreneur but not to a low-type entrepreneur. If Government has chosen *NSC* in the previous phase, it does not observe the true type of the entrepreneur.

5. Payoffs are realized as shown below.

Figure 2 shows the extensive-form representation of the game.

Government's belief in the non-singleton information sets, θ, is determined ylBayes' Rule using the prior probabilities and the equilibrium strategies. If Government finds out the true type of the entrepreneur (screens) it gives a grant to a high-type entrepreneur but not to a low-type entrepreneur. Government has three different strategies: (*SC, S* if *H, NS* if *L*), (*NSC, S*) and (*NSC, NS*). In the following I refer to the first strategy as *SC*.

The payoffs related to different Government strategies are presented below. All the payoffs are presented as net profits. At this point it is assumed that if an entrepreneur is granted a subsidy she also gets the additional market-based funding needed. In other words, it is assumed that with the subsidy an entrepreneur can launch an innovation project that would not be undertaken otherwise.[4] Payoff $\Pi_j^{G,i}$ refers to Government's payoff when the type of the entrepreneur is i and Government strategy is j. Government's payoffs related to different strategies when the applicant is of a high-type are

$$\Pi_{SC}^{G,H} = \lambda_H(R_H + W_H) - I - gS - c - \sigma \tag{8}$$

$$\Pi_{NSC,S}^{G,H} = \lambda_H(R_H + W_H) - I - gS - c \tag{9}$$

$$\Pi_{NSC,NS}^{G,H} = -c \tag{10}$$

and when the applicant is of a low-type

$$\Pi_{SC}^{G,L} = -c - \sigma \tag{11}$$

$$\Pi_{NSC,S}^{G,L} = \lambda_L R_L - I - gS - c \tag{12}$$

$$\Pi_{NSC,NS}^{G,L} = -c. \tag{13}$$

In the following $W_H + R_H = W$ and $I + gS = I^S$.

A high-type entrepreneur gets a subsidy if Government follows either the strategy *SC* or the strategy (*NSC,S*) and if Government follows the strategy (*NSC, NS*) she does not get a subsidy. Similarly, if Government follows either the strategy *SC* or the strategy (*NSC, NS*), a low-type entrepreneur does not get a subsidy, but if Government chooses the strategy (*NSC,S*) she gets a subsidy. In the following $\Pi_S^{E,i}$ and $\Pi_{NS}^{E,i}$ refer to the payoff of an i-type entrepreneur when she gets a subsidy and when she does not get a subsidy respectively. A high-type entrepreneur's payoffs from different Government strategies are

[4] This assumption is qualitatively in line with reality, since in practice R&D subsidies are paid against incurred costs. If a project does not get market-based financing, the project cannot be launched and the subsidy will not be paid.

$$\Pi_S^{E,H} = \lambda_H[R_H - F^S] - A \tag{14}$$

$$\Pi_{NS}^{E,H} = -c \tag{15}$$

and low-type entrepreneur's related strategies are

$$\Pi_S^{E,L} = \lambda_L[R_L - F^S] - A \tag{16}$$

$$\Pi_{NS}^{E,L} = -c. \tag{17}$$

F^S in the entrepreneur's payoff function is the share of financial return of a successful project the entrepreneur must give to the market-based financier if the project succeeds. The focus is on entrepreneurs that face financing constraints and entrepreneurs do not get market-based financing without a subsidy. Therefore the financier's share of financial return of a successful project is now different than above. It will be specified in section four.

3.1 Assumptions related to Government screening process

There are two assumptions underlying the Government screening process.

A1. Government can identify the quality of projects according to its predefined criteria.

A2. It is optimal for Government to screen projects, even if screening is not optimal for external financiers. For simplicity it is assumed that external financiers do not screen.

A1 means that I do not question public sector's ability to pick the 'winners' and 'losers' according to its funding policy. In general the funding policy consists of criteria related to expected social and private returns of the innovation projects.

A2 is probably a more problematic one and may seem rather bold at first sight. However, there are several factors that may support A2, especially in the case of a small country like Finland.

First of all, information acquisition may be easier for the public financier allocating R&D subsidies. Firms may be more willing to reveal confidential information about their innovation projects to a public agency than to a private financier. In addition, at least in the Finnish case, the public financier constitutes a centralized screening device. It receives a large amount of applications that it can compare against each other. As a result, the public financier could be expected to have quite a good overview about the state of the art in each relevant field.

Second, the objectives of a public financier and an external financier are often somewhat different. A public financier is not only interested in the financial return generated by a project but takes into account also the overall social benefits. Moreover the public financier is often granting project specific funding, whereas external financiers operate purely at the firm level. Third, there seems to be a common impression that the financial markets, especially the banking sector in Finland, has a rather underdeveloped screening technology.

3.2 Criteria determining the type of equilibria in question

Since the game in question is a dynamic game of incomplete information the equilibrium concept used is Perfect Bayesian equilibrium (PBE). A PBE in this game is a set of entrepreneur's and public financier's strategies and public financiers beliefs such that, at any stage of the game, strategies are optimal given beliefs, and the beliefs are obtained from equilibrium strategies and observed actions using Bayes' rule.

I restrict the analysis to equilibria in which high-type entrepreneurs always apply.[5] Since a pure-strategy equilibrium is an equilibrium in degenerate mixed strategies, I focus on mixed strategies. The interest is on mixed-strategy equilibria in which a high-type entrepreneur always applies, a low-type entrepreneur applies with probability μ ($\mu = 0$) and Government randomizes between strategies *SC*, (*NSC, S*) and (*NSC, NS*) with probabilities α_{SC}, $\alpha_{NSC,S}$and $1 - \alpha_{SC} - \alpha_{NSC,S}$ ($\alpha_{SC}, \alpha_{NSC,S} \geq 0$).

Given the above Government strategies and payoffs specified in equations (14) and (15), the expected payoff of a high-type entrepreneur from applying is

$$E(\Pi_{AP}^{E,H}) = (\alpha_{SC} + \alpha_{NSC,S})\Pi_S^{E,H} + (1 - \alpha_{SC} - \alpha_{NSC,S})\Pi_{NS}^{E,H}. \quad (18)$$

If a high-type entrepreneur does not apply for a subsidy her net payoff is zero.

[5] It can be shown that with the exception of the trivial case in which no one applies and Government does not grant subsidies high-type entrepreneurs always apply.

The assumption that high-type entrepreneurs always apply implies that in equilibrium, the condition

$$E(\Pi_{AP}^{E,H}) > 0 \tag{19}$$

must hold. Otherwise it is not optimal for a high-type to always apply.

Since a low-type entrepreneur is using a mixed strategy (μ,1-μ), Government's belief that an applicant is of a high-type is given by θ.

$$\theta = \frac{p}{p + \mu(1-p)}. \tag{20}$$

Government's expected payoff from screening is

$$E(\Pi_{SC}^{G}) = \theta[\lambda_H W - I^S] - c - \sigma, \tag{21}$$

from (*NSC, S*)

$$E(\Pi_{NSC,S}^{G}) = \theta[\lambda_H W] + (1-\theta)\lambda_L R_L - I^S - c, \tag{22}$$

and from (*NSC, NS*) the payoff is -*c*.

3.3 Optimal strategies for Government

Government's best response to a low-type's mixed strategy (μ,1-μ) depends on the value of μ. If μ is such that $E(\Pi_{SC}^{G}) > E(\Pi_{NSC,S}^{G})$ and $E(\Pi_{SC}^{G}) > -c$, it is optimal for Government to choose *SC*. If $E(\Pi_{SC}^{G}) < E(\Pi_{NSC,S}^{G})$ and $E(\Pi_{NSC,S}^{G}) > -c$, then it is optimal for Government to choose (*NSC, S*) and if both $E(\Pi_{SC}^{G})$ and $E(\Pi_{NSC,S}^{G})$ are smaller than -*c*, it is optimal for Government to follow the strategy (*NSC, NS*). Whenever the payoffs are equal, Government is indifferent between the corresponding strategies. Substituting (20) for θ in (21) and (22) and solving the above inequalities for μ give us the following strategy for Government.[6]

When $\underline{L} < \bar{L}$ the following strategy holds:

- If $\mu < \underline{L}$, the best strategy for Government is (*NSC, S*) ($\alpha_{NSC,S} = 1$).
- If $\underline{L} < \mu < \bar{L}$, the best strategy for Government is *SC* ($\alpha_{SC} = 1$).

[6]If $\mu = \bar{L} = \underline{L}$ Government is indifferent between all the three strategies and uses a mixed strategy randomizing between all the three pure strategies. However, this equilibrium exists only for a trivial set of parameters and is thus not analyzed further. Namely, when $\sigma = \frac{(I^S - \lambda_L R_L)(\lambda_H W - I^S)}{\lambda_H W - \lambda_L R_L}$ and $p \leq \frac{I^S - \lambda_L R_L}{\lambda_H W - \lambda_L R_L}$. In figure 3, this set is one line.

- If $\mu > \bar{L}$, the best strategy for Government is (*NSC, NS*) $(1 - \alpha_{SC} - \alpha_{NSC,S} = 1)$.
- If $\mu = \underline{L}$, Government is indifferent between *SC* and (*NSC, S*).
- If $\mu = \bar{L}$, Government is indifferent between *SC* and (*NSC, NS*).

When $\underline{L} > \bar{L}$ the following strategy holds:

- If $\mu < \hat{L}$, the best strategy for Government is (*NSC, S*) $(\alpha_{NSC,S} = 1)$.
- If $\mu > \hat{L}$, the best strategy for Government is (*NSC, NS*) $(1 - \alpha_{SC} - \alpha_{NSC,S} = 1)$.
- If $\mu = \hat{L}$, Government is indifferent between (*NSC, NS*) and (*NSC, S*).

In the above $\underline{L} = \left(\frac{p}{1-p}\right)\left(\frac{\sigma}{I^S - \lambda_L R_L - \sigma}\right)$, $\bar{L} = \left(\frac{p}{1-p}\right)\left(\frac{\lambda_H W - I^S - \sigma}{\sigma}\right)$ and $\hat{L} = \left(\frac{p}{1-p}\right)\left(\frac{\lambda_H W - I^S}{I^S - \lambda_L R_L}\right)$. The order of $\underline{L}$and $\bar{L}$ and the magnitude of $\underline{L}$, $\bar{L}$ and $\hat{L}$ - and thus the set of sensible Government strategies - depends on the values of σ and p.

Figure 3 presents, sensible strategies for different sets of values of parameters σ and p. The figure identifies four different regions. Note that based on Proposition 1, we know that in the presence of financing constraints $p \leq \frac{I - \lambda_L R_H}{\Delta\lambda R_H}$. In regions 1 and 2, screening is a plausible strategy, whereas in regions 3 and 4 the combinations of p and σ are such that screening is never optimal. In region 3 it is always optimal for Government to grant a subsidy without screening. In other words, the screening costs are so high compared to the relatively high share of high-type entrepreneurs in the population that it is optimal for Government just to grant a subsidy to every applicant. In region 4 Government chooses between the two strategies (*NSC, S*) and *(NSC, NS)*.

Proposition 2 *Screening is a plausible strategy for Government if*
$\sigma \leq min\left\{\frac{(I^S - \lambda_L R_L)(\lambda_H W - I^S)}{\lambda_H W - \lambda_L R_L}, (1-p)(I^S - \lambda_L R_L)\right\}$.

Proposition 2 identifies the region of which this paper is interested in. Here the aim is to analyze the screening activities of Government, so I consider regions 1 and 2 and restrict σ to fulfill the condition presented in Proposition 2. This restriction implies that $\underline{L} < \bar{L}$ and therefore the relevant strategy of Government follows the one that is valid when $\underline{L} < \bar{L}$ holds. In addition this parameter

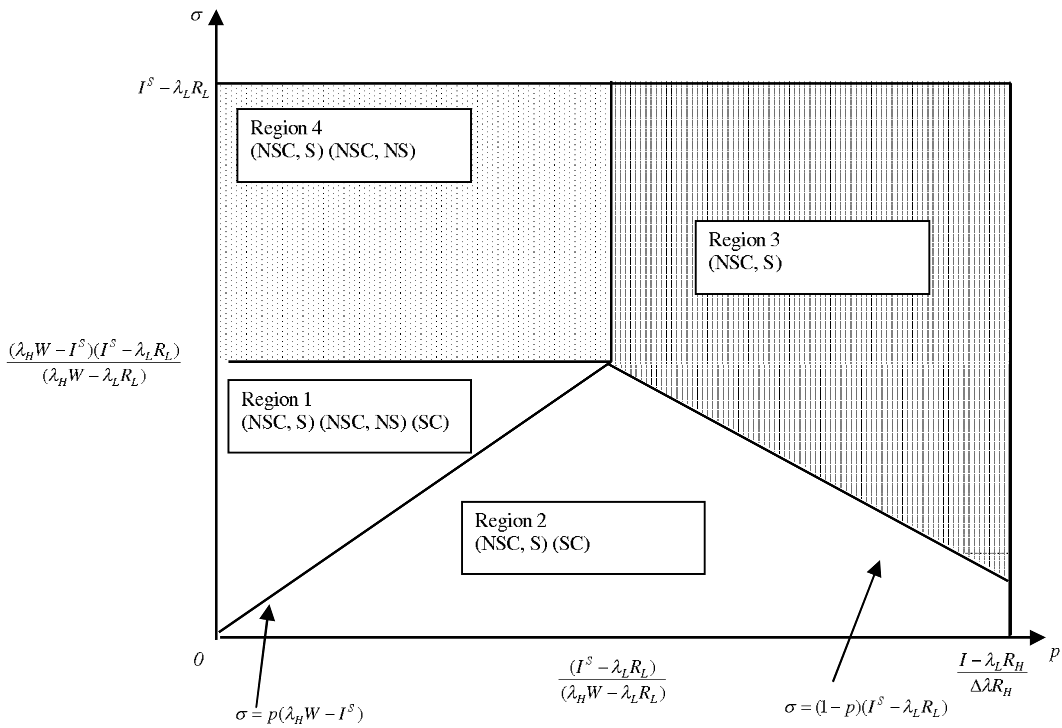

Figure 3: Plausible Government strategies with different values of screening costs (σ) and different share of high-type entrepreneurs in the economy (p)

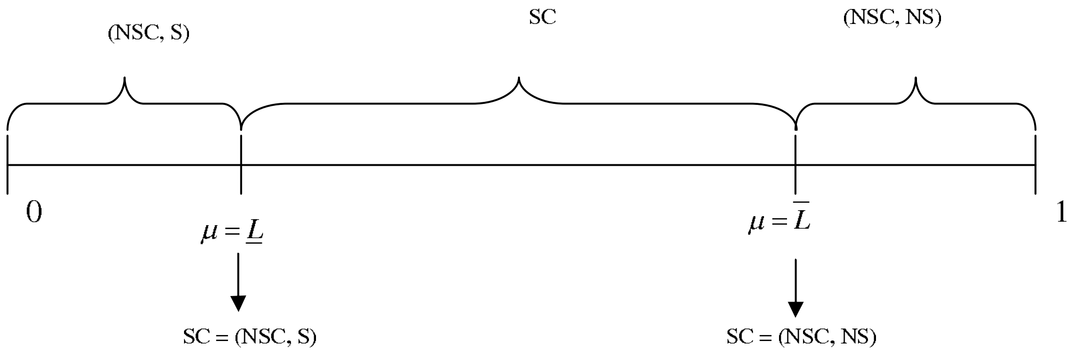

Figure 4: Optimal strategies for Government with different values of μ

restriction rules out the unrealistic case that if all entrepreneurs apply it is never optimal for Government to just grant subsidies to all.[7]

Within the region of interest, the plausible strategies for Government depend on whether $\bar{L}$ is greater or smaller than one. If $\bar{L}$ is greater than one, then the strategy (*NSC, NS*) is not a plausible option for Government. In practice $\bar{L}$ is smaller than 1 only if $\sigma > p(\lambda_H W - I^S)$. The intuition is that (*NSC, NS*) is a plausible strategy for Government only if screening costs are high relative to the share of high-type entrepreneurs in the population.

Figure 4 below summarizes the optimal strategies for Government. Note that if $\bar{L}$ is larger than 1, the area in which screening is the optimal strategy extends to one and (*NSC, NS*) is no longer a plausible strategy for Government.

3.4 Optimal strategies for a low-type firm

Low-type entrepreneur's expected payoff from applying given that Government follows a mixed strategy $(\alpha, \alpha_{NSC,S}, 1 - \alpha_{SC} - \alpha_{NSC,S})$ is

$$E(\Pi_{AP}^{E,L,}) = (1 - \alpha_{NSC,S})\Pi_{NS}^{E,L} + \alpha_{NSC,S}\Pi_{S}^{E,L} \tag{23}$$

and from not applying zero.

If $E(\Pi_{AP}^{E,L}) < 0$, it is optimal for a low-type entrepreneur not to apply. If $E(\Pi_{AP}^{E,L}) = 0$, low-type entrepreneur is indifferent, and uses a mixed strategy (μ,1-μ). Substituting equation (16) for $\Pi_{S}^{E,L}$ and equation (17) for $\Pi_{NS}^{E,L}$ in equation (23) and solving the inequalities, gives the following strategy for a

[7]Substituting p for θ in equations (20) and (21) gives that (SC) is better than (NSC,S) if $\sigma < (1-p)(I^S - \lambda_L R_L)$ and (NSC, NS) is better than (NSC, S) if $p < \frac{I^S - \lambda_L R_L}{\lambda_H W - \lambda_L R_L}$.

low-type entrepreneur:

- If $\alpha_{NSC,S} > \frac{c}{\lambda_L(R_L - F^S) - A + c}$, the best strategy for a low-type entrepreneur is to apply ($\mu = 1$).
- If $\alpha_{NSC,S} < \frac{c}{\lambda_L(R_L - F^S) - A + c}$, the best strategy for a low-type entrepreneur is not to apply ($\mu = 0$).
- If $\alpha_{NSC,S} = \frac{c}{\lambda_L(R_L - F^S) - A + c}$, a low-type entrepreneur randomizes between applying and not with probabilities μ and (1- μ).

3.5 Outcome of the game

We can now state the main result of this section.

Proposition 3 *In a PBE of the game*

- *Government's belief that the applicant is of a high type is determined by* $\theta = \frac{I + gS - \lambda_L R_L - \sigma}{I + gS - \lambda_L R_L}$.
- *A high-type entrepreneur always applies.*
- *A low-type entrepreneur applies with probability* $\mu = \underline{L} = \left(\frac{p}{1-p}\right)\left(\frac{\sigma}{I + gS - \lambda_L R_L - \sigma}\right)$.
- *Government randomizes between SC and (NSC, S) with probabilities* $\alpha_{SC} = \frac{\lambda_L(R_L - F^S)}{\lambda_L(R_L - F^S) - A + c}$ *and* $\alpha_{NSC,S} = \frac{c}{\lambda_L(R_L - F^S) - A + c}$.

PROOF. There is no pure strategy equilibrium in this game. If a low-type entrepreneur always applies, $\alpha_{NSC,S} > \frac{c}{\lambda_L(R_L - F^S) - A + c}$ must hold. However, if $\mu = 1$, it is optimal for Government to choose (*NSC, NS*), implying that $\alpha_{NSC,S} = 0$. If a low-type entrepreneur never applies then $\alpha_{NSC,S}$ must be smaller than $\frac{c}{\lambda_L(R_L - F^S) - A + c}$. But if $\mu = 0$, it is optimal for Government to set $\alpha_{NSC,S} = 1$, which is larger than $\frac{c}{\lambda_L(R_L - F^S) - A + c}$.$\square$

For a low-type to be willing to use a mixed strategy (μ,1-μ), $\alpha_{NSC,S}$ must be equal to $\frac{c}{\lambda_L(R_L - F^S) - A + c}$. Given that $\alpha_{NSC,S} > 0$, the only possible mixed strategy for Government is to randomize between *SC* and (*NSC,S*) with probabilities $\alpha_{NSC,S} = \frac{c}{\lambda_L(R_L - F^S) - A + c}$ and $\alpha_{SC} = \frac{\lambda_L(R_L - F^S)}{\lambda_L(R_L - F^S) - A + c}$. This Government strategy satisfies $\alpha_{SC} + \alpha_{NSC,S} > \frac{c}{\lambda_H(R_H - F^S) - A + c}$, as required by the assumption that high-type entrepreneurs always apply. When Government randomizes between SC and (NSC,S), a low-type entrepreneur applies with probability $\mu = \underline{L} = \left(\frac{p}{1-p}\right)\left(\frac{\sigma}{I+gS-\lambda_L R_L-\sigma}\right)$. $\square$

The above equilibrium is based on the assumption that the subsidy program is in place and Government chooses whether to screen or not. In other words, the possibility to just close the program is not taken into account. If Government chooses to close the whole program, the payoff is zero to both entrepreneur and Government (possible costs related to the closing of the subsidy program are not considered here). If the above equilibrium generates a larger payoff to Government than zero then it is optimal, even if closing the subsidy program is a plausible strategy. It can be shown that the above equilibrium remains optimal with minor modifications to the restriction imposed on σ in Proposition 2.[8]

Comparative statistics of the Government screening probability are somewhat involved, since the screening probability depends on F^S, the share of financial return of a successful project the entrepreneur must give to the market-based financier if the project succeeds. F^S will be defined below in section 4, but here it suffices to say that the parameters of F^S include S, c, α_{SC} and θ. Appendix 1 presents the partial derivatives of the screening probability with respect to σ, c, A and S. Those are computed by implicit differentiation. The sign of all the calculated partial derivatives depends on the sign of the common denominator. If it is assumed that the denominator is positive, the results are intuitive:[9] an increase in the screening cost, or in the application cost, or in the initial wealth decreases the screening probability, whereas an increase in the subsidy increases the screening probability.

The mixed strategy for Government can be interpreted as Government deciding on the intensity of screening. The higher is the probability of screening versus automatically granting a subsidy, the higher is the screening intensity and the higher is the probability of finding out the true type of the project. If the probability of screening is equal to one, screening is perfect and Government finds out the true type of the project for sure.

When looking at low-type's optimal strategy it can be noted that an increase in the screening cost increases low-type's application probability, as could be expected, but an increase in the subsidy decreases the application probability. The latter outcome may seem counterintuitive, but it is explained by the screening

[8]Instead of $\sigma \leq \frac{(I^S-\lambda_L R_L)(\lambda_H W-I^S)}{\lambda_H W-\lambda_L R_L}$ we have $\sigma \leq \frac{(I^S-\lambda_L R_L)(\lambda_H W-I^S-c)}{\lambda_H W-\lambda_L R_L}$.

[9]Due to rather cumbersome equations, it is difficult to explicitly prove that the denominator is positive. What can be shown though, is that there exists an interval in which the denominator is positive.

probability that increases with S. If S increases, low-type entrepreneurs anticipate an increase in the screening probability and are less likely to apply.

4 Government R&D subsidies and external finance

Suppose now that the entrepreneurs can first apply for an R&D subsidy from Government, and then seek market-based financing from other sources. Suppose further that the outside financier observes whether the entrepreneur has received an R&D subsidy or not, and it knows how Government funding policy works. The subsidy observation provides additional information to the market-based financier about the type of the project. Then, if the entrepreneur has been granted a subsidy, outside financiers' participation constraint reads as

$$I - A - S + c \leq \hat{\lambda} F^S. \tag{24}$$

$\hat{\lambda}$ is the success probability anticipated by the financier, if the entrepreneur has received an R&D subsidy, and it is determined by

$$\hat{\lambda} = P(H|S)\lambda_H + [1 - P(H|S)]\lambda_L. \tag{25}$$

$P(H|S)$ is the conditional probability that the entrepreneur is of a high-type, given that she has received an R&D subsidy from Government. In equilibrium, Government randomizes between SC and (NSC, S) with probabilities α_{SC} and $1 - \alpha_{SC}$. This means that $P(H|S) = \hat{p} = \alpha_{SC} + (1 - \alpha_{SC})\theta$. If an entrepreneur has not received a subsidy, the financier knows for sure that she is a low-type entrepreneur. Given competitive financial markets, equation (24) holds with equality and the share of a successful project given to a financier is

$$F^S = \frac{I - A - S + c}{\hat{\lambda}}. \tag{26}$$

The entrepreneur's participation constraint remains $\lambda_i R_i^E \geq A$, since in order to receive an R&D subsidy the entrepreneur has to invest initial wealth in the project. We assume that in the funding gap region that we are focusing on, entrepreneurs need external market-based financing in addition to the subsidy in order to undertake the innovation project ($A + S < I$). The pledgeable income that can be offered to the financier is $R_i^F = R_i - R_i^E = R_i - \frac{A}{\lambda_i}$ as above.

An entrepreneur with an R&D subsidy can get market-based financing if

$$\frac{I - A - S + c}{\hat{\lambda}} \leq R_H - \frac{A}{\lambda_H}. \tag{27}$$

The right hand side of the equation (27) is the pledgeable income that a high-type entrepreneur is willing to offer to the financier, and it is the same as without a subsidy program. Solving equation (27) for A shows that if the entrepreneur has been granted an R&D subsidy, the outside financiers grant funds if

$$A \geq \bar{A}^S \equiv \frac{\lambda_H}{\lambda_H - \hat{\lambda}}[I - S + c - \hat{\lambda} R_H].$$

Proposition 4 *Entrepreneurs with an R&D subsidy can get market-based financing with less initial capital, i.e.* $\bar{A} > \bar{A}^S$*, if* $\hat{\lambda} \geq \bar{\lambda}$.

PROOF. $\bar{A} > \bar{A}^S \Leftrightarrow \left(\frac{\lambda_H}{\lambda_H - \bar{\lambda}}\right)(I - \bar{\lambda} R_H) > \left(\frac{\lambda_H}{\lambda_H - \hat{\lambda}}\right)(I - S + c - \hat{\lambda} R_H) \Leftrightarrow (\hat{\lambda} - \bar{\lambda})(\lambda_H R_H - I) + (\lambda_H + \bar{\lambda})(S - c) > 0$. From the last inequality we can see that it holds if $\hat{\lambda} \geq \bar{\lambda}$. High-type projects are economically viable, therefore $\lambda_H R_H - I > 0$. Since we are analyzing entrepreneurs that have been granted an R&D subsidy, $(\lambda_H + \bar{\lambda})(S - c) > 0$, if $S > c$ and $\bar{A} > \bar{A}^S$ even if $\hat{\lambda} = \bar{\lambda}$. □

Proposition 5 *Due to Government screening, the fact that an entrepreneur has received an R&D subsidy provides an informative signal to the financier, i.e.* $\hat{\lambda} > \bar{\lambda}$.

PROOF. $\hat{\lambda} = \hat{p}\lambda_H + (1 - \hat{p})\lambda_L > \bar{\lambda}$, if $\hat{p} > p$. Knowing that $\hat{p} = \alpha_{SC} + (1 - \alpha_{SC})\theta$ gives us that for $\hat{p} > p$, α_{SC} must satisfy $\alpha_{SC} > \frac{p - \theta}{1 - \theta}$. This is true since $p < \theta = \frac{p}{p + \mu(1 - p)} < 1$ ($0 < p < 1$ and $0 < \mu < 1$). □

Figure 5 shows how the funding gap region presented in Figure 1 changes as a result of the introduction of a subsidy program. From equation (1) we know that $\hat{A} \equiv \frac{\lambda_L \lambda_H \Delta R}{\Delta \lambda}$ and it does not change when a subsidy program is introduced, since the participation constraint of an entrepreneur remains the same. What happens is that the $\bar{A}$-curve shifts downward. Whether the shift reduces financial constraints depends on the value of $\hat{p}$.

Proposition 6 *R&D subsidy program reduces financial constraints, when* $p \in \left[\frac{(\hat{p} - \alpha_{SC})\mu}{(1 - \hat{p}) + (\hat{p} - \alpha_{SC})\mu}, \frac{I - \lambda_L R_H}{\Delta \lambda R_H}\right]$*, where* α_{SC} *and* μ *are the equilibrium strategies and* $\underline{\hat{p}} = \frac{I - S + c - \lambda_L R_L}{\lambda_H R_H - \lambda_L R_L}$.

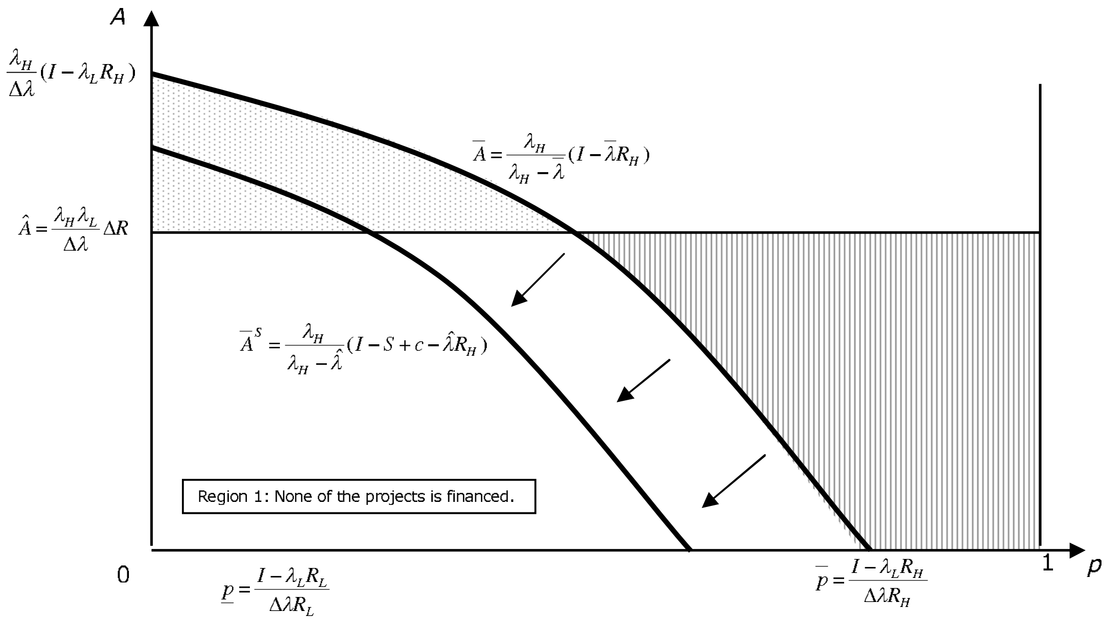

Figure 5: Change in Region 1, when a subsidy program is introduced

PROOF: $\bar{A} > \bar{A}^S$ must hold for a specific value of $\hat{p}$, if the subsidy program reduces financial constraints. It can be shown that $\bar{A} > \bar{A}^S \Leftrightarrow \hat{p} \geq \frac{I-S+c-\lambda_L R_L}{\lambda_H R_H - \lambda_L R_L} = \underline{\hat{p}}$. Proposition 1 gives that in the funding gap region $p < \frac{I-\lambda_L R_H}{\Delta\lambda R_H} = \bar{p}$. It can be shown that $\bar{p} > \underline{\hat{p}}$. In addition we know from Proposition 5 that for a given p, $\hat{p} > p$, so the lower bound of p is smaller than $\underline{\hat{p}}$. Substituting for $\frac{p}{p+\mu(1-p)}$ for θ in $\hat{p} = \alpha_{SC} + (1-\alpha_{SC})\theta$ gives the implicit form for p as a function of $p, \hat{\alpha}_{SC}$ and μ that is $p = \frac{(\hat{p}-\alpha_{SC})\mu}{(1-\hat{p})+(\hat{p}-\alpha_{SC})\mu}$. Substituting $\underline{\hat{p}}$ for $\hat{p}$ gives the lower bound of p in the implicit form and the interval in Proposition 6. □

Propositions 4, 5 and 6 summarize the main result. R&D subsidies and more importantly the related screening process can help financially constrained entrepreneurs to get external financing for their innovation projects, if the share of high-type entrepreneurs in the population is sufficiently high. Two different channels generate this effect. The first one presented in Proposition 4 is a trivial one: a subsidy reduces the amount of external capital needed, thus reducing capital costs. The more important channel is the second one presented in Proposition 5: subsidy observation provides additional information to external financiers about the quality of the project. With this additional information, external financiers are willing to fund entrepreneurs with a subsidy with a lower

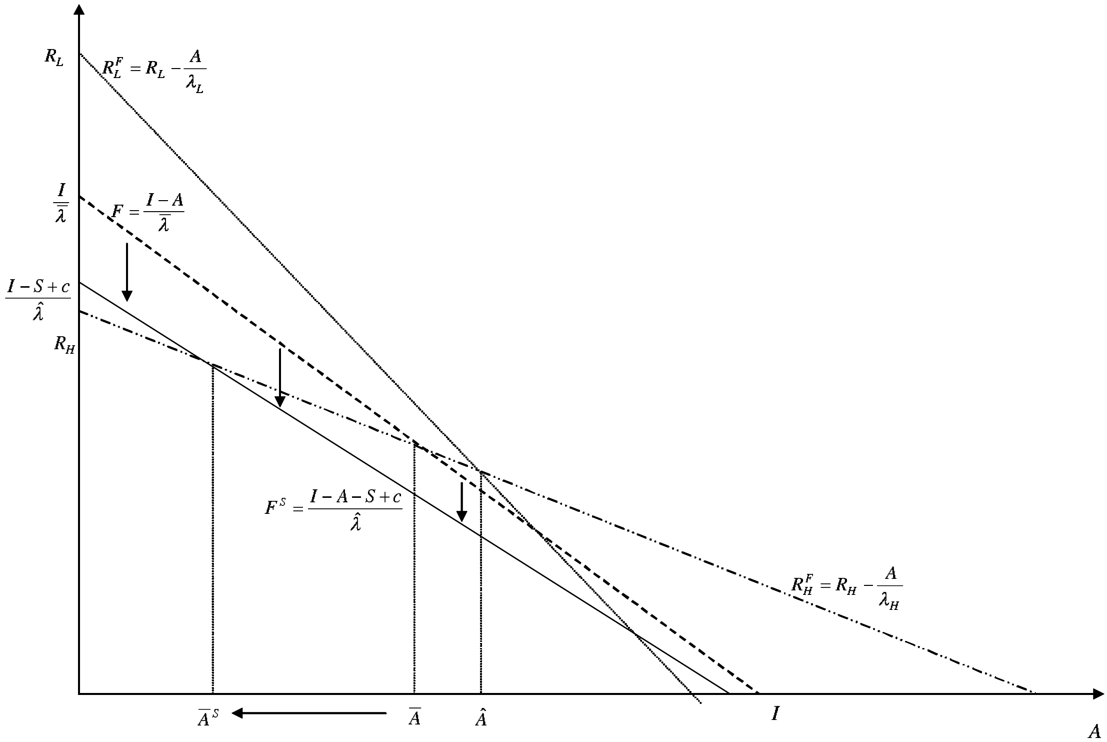

Figure 6: Change in funding gap region as a subsidy program is introduced

rate of return and this reduces the funding gap.

The expected total welfare effect of R&D subsidies to a society, with p belonging to the interval stated in Proposition 6, depends on the distribution of initial wealth. What happens is that the initial wealth required to get external financing becomes smaller, i.e. $\bar{A}$ is transformed to $\bar{A}^S$. Figure 6 presents the share of a successful project that a low-type entrepreneur is willing to promise to financier R_L^F, the share of a successful project that a high-type entrepreneur is willing to promise to financier R_H^F, the share of a successful project that a financier requires in order to invest in the project without a subsidy F and with a subsidy F^S. When a subsidy program is introduced the share of a successful project that a financier requires in order to invest in the project declines from F to F^S and as a result the funding gap region reduces from $[0, \bar{A}]$ to $[0, \bar{A}^S]$.

The expected net benefit to the society from one project that has received a subsidy is

$$E(\Pi^G) = \alpha_{SC} E(\Pi^G_{SC}) + (1-\alpha_{SC}) E(\Pi^G_{NSC,S}).$$

In equilibrium Government is indifferent between the strategies *SC* and *NSC,S*, which implies that the expected payoffs from these two strategies are equal. This gives

$$E(\Pi^G) = E(\Pi^G_{SC}) = E(\Pi^G_{NSC,S}) = \frac{(I^S - \lambda_L R_L)(\lambda_H W - I^S - c) - \sigma(\lambda_H W - \lambda_L R_L)}{I^S - \lambda_L R_L}$$

Depending on the value of σ this can be either positive or negative. If

$$\sigma < \frac{(I^S - \lambda_L R_L)(\lambda_H W - I^S - c)}{\lambda_H W - \lambda_L R_L)}$$

then $E(\Pi^G)$ is positive.[10] The expected total net benefit to the society depends on the share of entrepreneurs whose initial wealth is in the interval $[\bar{A}^S, \bar{A}]$. If the population of entrepreneurs is N, then the total net benefit to the society is

$$\left(\int_{\bar{A}^S}^{\bar{A}} G(A) dA \right) N \left(E(\Pi^G) \right).$$

.

Clearly the outcome is not the first-best: also some low-type entrepreneurs are financed. However, if the total net benefit to the society is positive, the subsidy program improves the market outcome under asymmetric information.

5 Conclusions

This study examined the role of R&D subsidies in reducing financial constraints created by adverse selection. Financial constraints are one of the rationales used to justify government intervention in the form of R&D subsidies. The findings of this study provide insights into under which conditions and through which channels R&D subsidies could be expected to alleviate financial constraints. The following conclusions can be drawn:

- Asymmetric information about the quality of R&D projects creates financing constraints for collateral-poor firms, if there is non-negligible share of

[10] Note that this restriction on σ is the same as the one derived by taking into account the possibility that Government can close down the program, see footnote 8.

non-viable projects within the economy.

- R&D subsidy policies that involve screening of the projects are sustainable, if the screening costs are low enough.
- The higher the expected loss generated by low-quality projects and the lower the share of high-quality projects within the economy, the higher the screening costs can be without rendering screening activities unsustainable.
- Under the above circumstances R&D subsidies can reduce financing constraints. This effect is generated through two different channels: 1) The subsidy in itself reduces the cost of external capital because the need for market-based financing diminishes. 2) If market-based financiers can observe that a project has received a subsidy from the public agency, the subsidy provides an informative signal about the quality of the R&D project. A subsidy-observation increases the success probability of the project anticipated by the market-based financier. This reduces the cost of external capital for subsidized projects.

These findings highlight that the screening activities related to R&D subsidy policies can have a role of their own in reducing financial constraints. Instead of allocating subsidies, the public agency could have a certification role and yet reduce the financing constraints. Lerner (2002) provides this kind of certification hypothesis when discussing about public venture capital programs. Granting funding strengthens the leverage effect, however. This raises the question of whether, in terms of financial constraints, it would suffice to reduce the asymmetry of information through screening.

If we consider screening to be the solution to the financial constraints, an additional question is: do we need a public screening agency or are there ways to increase the screening activities of market based financiers? This paper discussed, why it may be the case that a public agency is more efficient in its screening activities than a market based financier. However, we do not know whether this is the case or not, and under which circumstances. It could also be argued that public screening activities only crowed out private ones and hinder the development of efficient screening technologies in financial market.

The analysis in this paper assumed that the public financier can identify projects that suffer from financing constraints. If this does not hold then also entrepreneurs belonging to other regions presented in Figure 1 may end up getting subsidies. The implications on the total welfare are ambiguous. On one hand, high-type entrepreneurs not in need of subsidies may receive subsidies which is socially costly. On the other hand, the screening activities of the public financier may prevent some low-type entrepreneurs from getting market-based financing.

The crucial assumption underlying the results not discussed above is that the projects differ both in terms of success probability and in terms of financial return generated by a successful project such that higher return in the case of success is associated with lower success probability. Could this kind of a pool of applicants be relevant for R&D subsidy policies in practice? In Finland, the National Funding Agency for Technology and Innovation (Tekes) stresses that the *funding is meant for challenging innovation projects, some of which will hopefully lead to global success stories* (www.tekes.fi/eng/tekes/rd, accessed on October 9, 2006). At first sight this may seem that Tekes is especially interested in the kind of projects described as low-quality project in this study. Whether this is the case, depends on how the challenge-payoff-uncertainty combinations of proposed projects differ on average from the combination desired by Tekes.

It may be the case that firms rather tend to submit applications concerning projects with less challenging, highly predictable outcomes combined with marginal economic benefit. Then the selection at Tekes should be about picking the most challenging projects with high business potential - and with higher uncertainty. This case would be in contradiction of the assumption made in this paper.

However, another alternative may be the case that firms rather tend to submit applications concerning ambitious projects with high developmental challenge and high returns if successful, but incorporating greater uncertainty. Then the task of Tekes would be to sort out the overly optimistic, unrealistic projects. This is the case supporting the setup in this study.

The findings suggest that under certain conditions R&D subsidy policies can be welfare improving. However, the outcome is not fully efficient - also some low-quality projects are funded. An important question not tackled in this paper is, if another kind mechanism could improve the situation more efficiently than R&D subsidy programs. If direct government intervention is needed, can more efficient policies be designed? Or, could it be more efficient for example to support the development of functioning market mechanisms addressing the problem of financial constraints that small, innovative firms may be facing?

References

[1] Akerlof, George A. (1970): The Market for 'Lemons': Quality Uncertainty and the Market Mechanism, *Quarterly Journal of Economics*, 84, 488-500.

[2] Alam, P. and K. S. Walton (1995): Information Asymmetry and Valuation Effects of Debt Financing, *The Financial Review*, 30, 289-311.

[3] Albano, Gian Luigi and Alessandro Lizzeri (2001): Strategic Certification and Provision of Quality, *International Economic Review*, 42, 267-283.

[4] Amit, Raphael, James Brander and Christoph Zott (1998): Why Do Venture Capital Firms Exist? Theory and Canadian Evidence, *Journal of Business Venturing*, 13, 441-466.

[5] Auriol, Emmanuelle and Steven Schilizzi (2003): Quality Signaling through Certification, Theory and an Application to Agricultural Seed Market, IDEI Working Papers, 165.

[6] Besanko, David and Anjan V. Thakor (1987): Collateral and Rationing: Sorting Equilibria in Monopolistic and Competitive Credit Markets, *International Economic Review*, 28, 671-689.

[7] Bester, Helmut (1985): Screening vs. Rationing in Credit Markets with Imperfect Information, *The American Economic Review*, 75, 850-855.

[8] Bhattacharya, Sudipto and Jay R. Ritter (1983): Innovation and Communication : Signalling with Partial Disclosure, *Review of Economic Studies*, 50, 331-346.

[9] Blass, Asher A. and Oved Yosha (2003) Financing R&D in Mature Companies: An Empirical Analysis, *Economics of Innovation and New Technology*, 12, 425-447.

[10] Bond, Stephen, Dietmar Harhoff and John Van Reenen (2003): Investment, R&D and Financial Constraints in Britain and Germany, CEP Discussion Paper, No. CEPDP0599.

[11] Bougheas, S., H. Görg and E. Strobl (2001): Is R&D Financially Restrained? Theory and evidence from Irish Manufacturing, University of Nottingham Research Paper, 2001/16.

[12] Chan, Yuk-Shee, Stuart I. Greenbaum and Anjan V. Thakor (1986): Information Reusability , Competition and Bank Asset Quality, *Journal of Banking and Finance*, 10, 243-253.

[13] Da Rin, Marco, Giovanna Nicodano, Alessandro Sembenelli (2005): Public Policy and the Creation of Active Venture Capital Markets, European Central Bank Working Paper Series, No. 430.

[14] David, P., B. Hall & A. Toole (2000). Is Public R&D Complement or Substitute for Private R&D? A Review of the Econometric Evidence. *Research Policy*, 29, 497-529.

[15] De Meza, David and David C. Webb (1987): Too Much Investment: A Problem of Asymmetric Information, *The Quarterly Journal of Economics*, 102, 281-292.

[16] Diamond, Douglas W. (1989): Reputation Acquisition in Debt Markets, *The Journal of Political Economy*, 97, 828-862.

[17] Georghiou, Luke, Keith Smith, Otto Toivanen and Pekka Ylä-Anttila (2003): Evaluation of the Finnish Innovation Support System, Ministry of Trade and Industry Publications, 5/2003.

[18] Hall, Bronwyn H. (2002): The Financing of Research and Development, *Oxford Review of Economic Policy*, 18, 35-51.

[19] Hall, Bronwyn H. (1992): Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?: NBER Working Paper, No. 4096.

[20] Hao, K. and A. Jaffe (1993): Effect of Liquidity on Firms R&D Spending, *Economics of Innovation and New Technology*, 2, 275-82.

[21] Himmelberg, Charles P. and Bruce C. Petersen, R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries, *The Review of Economics and Statistics*, 76, 38-51.

[22] Holmström, B. and J. Tirole (1997): Financial Intermediation, Loanable Funds, and the Real Sector, *Quarterly Journal of Economics*, CXII, 663-691.

[23] Hubbard, R. G. (1998): Capital-Market Imperfections and Investment, *Journal of Economic Literature*, XXXVI, 193-225.

[24] Hyytinen, Ari and Mika Pajarinen (2002): Small business finance in Finland: A descriptive study, in Hyytinen, Ari and Mika Pajarinen (eds.), 2003, Financial Systems and Firm Performance: Theoretical and Empirical Perspectives, ETLA B:2.

[25] Klette. T. J., J. Møen and Z. Griliches (2000): Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies, *Research Policy*, 29, 471-495.

[26] Leland, H. E. and D. H. Pyle (1977): Informational Asymmetries, Financial Structure, and Financial Intermediation, *The Journal of Finance*, XXXII, 371-387.

[27] Lerner, Joshua (1998): Angel financing and public policy: An overview, *Journal of Banking & Finance*, 22, 773-783.

[28] Lerner, Joshua (2002):When bureaucrats meet entrepreneurs: The design of effective public venture capital programmes, *The Economic Journal*, 112, F73-F84.

[29] Myers, S. C. (1977): Determinants of Corporate Borrowing, *Journal of Financial Economics*, 5, 147-175.

[30] Myers, Stewart C. and Nicholas S. Majluf (1984): Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economic*s, 13, 187-221.

[31] Repullo, Rafael and Javier Suarez (2000): Entrepreneurial moral hazard and bank monitoring: A model of the credit channel, *European Economic Review*, 44, 1931-1950.

[32] Spence, A. M. (1973): Job market signaling, *Quarterly Journal of Economics*, 87, 355-379.

[33] Stenbacka, Rune and Mihkel M. Tombak (1998): Technology policy and the organization of R&D, *Journal of Economic Behavior & Organization*, 36, 503-520.

[34] Stiglitz, Joseph E. and Andrew Weiss (1981): Credit Rationing in Markets with Imperfect Information, *The American Economic Review*, 71, 393-410.

[35] Ueda, Masako (2004): Banks versus Venture Capital: Project Evaluation, Screening, and Expropriation, *The Journal of Finance*, LIX, 601-621.

Appendix 1

Partial derivatives of α_{SC} with respect to σ, c, A, and S.

$$\frac{\partial \alpha_{SC}}{\partial \sigma} = \frac{\lambda_L \left(\frac{\Delta\lambda \alpha_{SC}}{I^S - \lambda_L R_L}\right)(I - A - S + c)c}{[\hat{\lambda}(\lambda_L(R_L - F^S) - A + c)]^2 - \Delta\lambda(1-\theta)(I - A - S + c)c}$$

$$\frac{\partial \alpha_{SC}}{\partial c} = -\frac{\hat{\lambda}^2 \lambda_L \left(\hat{\lambda}(R_L - F^S) + c\right)}{[\hat{\lambda}(\lambda_L(R_L - F^S) - A + c)]^2 - \Delta\lambda(1-\theta)(I - A - S + c)c}$$

$$\frac{\partial \alpha_{SC}}{\partial A} = -\frac{\hat{\lambda}\left(\lambda_L + \hat{\lambda}\right) c}{[\hat{\lambda}(\lambda_L(R_L - F^S) - A + c)]^2 - \Delta\lambda(1-\theta)(I - A - S + c)c}$$

$$\frac{\partial \alpha_{SC}}{\partial S} = -\frac{\lambda_L \left[\hat{\lambda} + \Delta\lambda(1 - \alpha_{SC})\left(\frac{g\sigma}{(I_S - \lambda_L R_L)^2}\right)(I - A - S - c)\right] c}{[\hat{\lambda}(\lambda_L(R_L - F^S) - A + c)]^2 - \Delta\lambda(1-\theta)(I - A - S + c)c}$$

If we assume that the denominator is positive then $\frac{\partial \alpha_{SC}}{\partial \sigma} < 0$, $\frac{\partial \alpha_{SC}}{\partial c} < 0$, $\frac{\partial \alpha_{SC}}{A} < 0$ and $\frac{\partial \alpha_{SC}}{S} > 0$.

It can be shown that when $\theta = 1$ the denominator is positive. Moreover it can be shown that the denominator reaches it's minimum, which is negative, at a negative value of θ. As a function of θ, the denominator is an upward opening parabola, so there must be an interval of $\theta \in [\hat{\theta}, 1]$, where the denominator is positive. The restrictions imposed on σ and p imply that in the funding gap region $\theta \in \left[\frac{I^S - \lambda_L R_L}{\lambda_H W - \lambda_L R_L}, 1\right]$. So, although the exact value of $\hat{\theta}$ is not known, it can be said that there exists an interval of θ (and p) in which there are financially constrained high-type entrepreneurs and the denominator of the partial derivatives is positive.

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