Innovation Policy Reform*

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Abstract

Innovation policy is regarded important by both policy makers and academics. This paper analyzes optimal R&D tax credits and R&D subsidies. We base our counterfactual analysis on a structural treatment effect model of an R&D subsidies-only regime, and estimate its parameters by taking the model to Finnish R&D project data. We derive the optimal level of an R&D tax credit which turns out to be 17%. We find that optimal R&D tax credits and R&D subsidies generate higher R&D investments and spillovers than laizzer-faire regime wihout active innovation policies. However, active R&D policies generate only modest incerases in private profits. In terms of overall welfare neither optimal R&D tax credits nor R&D subsidies improve the situation over laissez-faire once the shadow cost of public funds is taken into account.

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1 Introduction

Investments in innovation are perceived both by academics and policy makers important for the enhancement of economic growth and welfare, and fraught with market failure. These perceptions are mirrored in actual innovation policy: different policies that seek to correct market failure(s) by increasing private sector investment in R&D have a central role in many developed countries (e.g. the EU Lisbon agenda, Small Business Innovation Research Program in the U.S.). The two main innovation policy tools are R&D subsidies and tax incentives for R&D. R&D subsidies are the second largest and fastest growing form of industrial support in OECD countries (Nevo [9]) and used by all OECD countries (Warda [**?**]). Also tax incentives for R&D are increasingly popular: 20 out of 27 OECD countries offered some form of R&D tax reliefs in 2006. Industrialized countries have also been active in changing their innovation policies: several countries have e.g. introduced R&D tax reliefs since the early 1990s.

There exists a large but inconclusive literature on the effects of both policy instruments on private R&D investments (Hall and van Reenen [4] survey the R&D tax credit and David, Hall and Toole [3] the R&D subsidy literature), yet essentially no empirical work that seeks to compare and contrast, let alone derive the optimal levels, of these two major tools of innovation policy. Given the importance of innovation, the size of perceived market failure(s) mirrored in the extent to which developed nations resort to using both R&D subsidies and tax incentives for R&D and the frequency of changes in policy, there seems to be a need to analyze innovation policy. The objective of this paper is to provide such an analysis.

To accomplish a comparison of different innovation policies, one has two possibilities. The first one is to collect data on policy changes, such as the recent movement in Norway from a subsidies only -regime to a regime of both subsidies and R&D tax credits (see Moen and Haegeland [8]). This approach would allow one to estimate the treatment effects of the policy (change). The second possibility is to build a structural model, estimate its parameters within a given policy regime and then use the structure and estimated parameters to answer counterfactual questions (see Heckman and Vytlacil [5, 6], Abbring and Heckman [1]). The latter approach has the added appeal that one can potentially solve for optimal new policies. We take this second route in this paper and study an economy, Finland, that only uses R&D subsidies. We keep the (policy) environment constant in other respects and study the following counterfactual questions: What are the welfare effects of an optimally designed innovation policy reform compared to i) no innovation policy, and ii) current policy? Do current R&D subsidies yield a higher or a lower social surplus than optimal R&D tax credits? Which firms benefit and which firms lose? What is the tax burden created by the optimal policy? What are the welfare effects of a tax credit policy whose tax consequences are limited to be equal to the current budget for R&D subsidies? We subject our findings to a number of robustness tests. [WE DON'T CURRENTLY ANSWER ALL THESE QUESTIONS].

We build on the recent work by Takalo, Tanayama and Toivanen [11] (henceforth TTT) who construct a structural model of the R&D subsidy allocation process and estimate it using Finnish R&D project level data. Besides offering high quality data for our purposes, Finland is an interesting case in its own right: e.g. Trajtenberg [12] has pointed out that Finland is one of the few countries that have managed to considerably improve their innovation performance over the last few decades. In Finland, only R&D subsidies are in use, although there is an ongoing debate about the introduction of an R&D tax credit. We assume throughout that the objectives of the government are those revealed by the structural estimation of the model in the R&D subsidy regime. This could be viewed as a strength of our approach as whatever the government objectives, we keep them constant over different policy regimes. We extend TTT's work in three ways: First, by bringing into the model corporate taxes; second, by estimating the model using improved data that allows us to control better for past innovative activities of firms through information on patents, past successes in the application process, R&D investments, and R&D employees; and third, by deriving the socially optimal level of an R&D tax credit, and the privately optimal R&D investments in the different regimes.

We find that an optimal R&D tax credit and R&D subsidies yield significantly higher R&D investment and spillovers than what would be generated by a laizzer-faire regime. The difference in private profits is however small. Both activist policies - R&D tax credits and R&D subsidies - yield outcomes that are close to each other. In terms of overall welfare all the three regimes amount to the same once we take into account the shadow cost of public funds.

We compare our estimated optimal R&D tax credit to tax incentives used in other countries, and find that its effective impact is somewhat above the average of actual policies, but well below the most generous tax treatments.[1] As our interpretation of our results is that domestic spillovers are so much smaller than private profits because Finland is a small open economy, one might expect that keeping everything else the same, large economies should have higher R&D tax credits than what we derive to be optimal for Finland. However, actual statistics about tax incentives for R&D do not provide support for this view.

The rest of the paper is organized as follows: we briefly describe the prevailing Finnish innovation policy model in the following section. In section three, we present the model. As the model is built around the existing Finnish policy of using R&D subsidies only, it at the same time characterizes what an (by assumption) optimal R&D subsidy policy looks like. Section four is devoted to deriving an optimal innovation policy reform. In this section we also derive the benchmark for active innovation policies. In section five we present our data. Section six is devoted to reporting our estimation results that form the base for our counterfactual calculations reported in section seven. We discuss robustness issuess in section eight. We then contrast our findings with the stylized facts of innovation policy in different countries in section nine before concluding the paper in section ten.

2 Finnish innovation policy

We confine ourselves to a discussion of public sector support to private

[1] [?] has reviewed the use of different innovation policy tools in OECD countries.

sector R&D. Since the early 1980s, the main policy tool of Finnish innovation policy has been the Finnish Funding Agency of Technology and Innovation, or Tekes. Tekes grants R&D subsidies, low-interest loans, and so-called capital loans. In 2001 (the middle year of our observation period) Finland invested 3.6 per cent of GDP – 5 billion euro - on R&D. Tekes is the principal public financier of private R&D in Finland. 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 this end Tekes strives to increase Finnish firms' R&D and risk-taking. Tekes is also responsible for allocating funding from European Regional Development Funds (ERDF), which is meant for the less-favored regions. Finnish regions are heterogenous: 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.

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. Almost exactly 2/3s of the nearly 3000 applications were accepted. The number of applications by the business sector for R&D funding was over 1300 of which 2/3 were accepted. Business sector subsidies amounted to over 200 million euros. Tekes' business R&D funding consists of grants, low-interest loans and capital loans.[2] The share of each instrument

[2] Low-interest loans are also soft in that if the project turns out to be a commercial failure, the loan may not have to be paid back. A capital loan granted is included in fixed assets in the balance sheet. A capital loan can be paid off only when unrestricted shareholders' equity is positive. Collateral cannot be part of a capital loan contract.

in 2001 was 69 %, 18% and 13% of the total funding allocated to business R&D. Subsidies' share of applications (granted amount) was 83 (67) %.

The application process runs as follows: First, a firm decides whether or not to apply for a subsidy. After receiving an application Tekes grades it and then decides on the subsidy level. This is subject to minimum (zero) and maximum (50 or 60% depending on whether or not the applicant is an SME) constraints. Our understanding is that this process is well known among potential applicants. In our analysis, we use the two most important (as declared by Tekes' officials in our discussions) grading dimensions: the technical challenge of the project, and the marketing risk of the project. 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 account whether the application comes from an SME. The funding also has a regional dimension through ERDF.

The purpose and the budget of the R&D project for which Tekes funding is needed are included in the application as is the applied amount of funding. Tekes' subsidy is granted as a share of to-be-incurred R&D costs. Actual funding is only given after the R&D investments are made. It covers the promised share of incurred costs up to a specified euro limit. The limit prevents Tekes from covering costs extraneous to the project proposal.

3 The model

In this section, we sketch the model. A more complete treatment can be found in TTT. Each firm has an idea. A shock to each idea determines its "quality", which we model as a shock to the marginal profitability of (log) R&D. This shock, and a shock to the cost of applying constitute the project's type in the model (conditional on observable firm characteristics). After receiving an idea and its quality, the firm has to determine whether or not to apply for a subsidy. TTT model this decision as a four stage game of incomplete information between the firm and the agency deciding on the subsidy. The firm has to decide whether or not to apply for a subsidy, not having perfect foresight on the agency's decision. The agency's type is three-dimensional: the first dimension is a shock to the externalities the project of the firm generates, but which the firm does not internalize. The other two are shocks to the projects two dimensions that are graded by the agency and that also affect the externalities. As applying is costly, some firms will in equilibrium decide not to apply. If a firm applies, the agency grades the application and decides on the optimal subsidy which can also be zero. The firm then decides on the optimal level of R&D. Given the adoped specification, the game has a unique Perfect Bayesian Nash equilibrium.

3.1 Objective functions

The firm's objective function is to maximize its expected discounted profits net of R&D investment by choosing the level of R&D:

$$\Pi_i = \pi_i + a_i \ln R_i - (1 - s_i) R_i \tag{1}$$

where π_i is the profit from ongoing other activities; a_i is the marginal return to R&D; R_i is the R&D investment; and s_i is the subsidy level. This generates the privately optimal level of R&D:

$$R_i = \frac{a_i}{(1 - s_i)}. \tag{2}$$

The agency maximizes its utility from R&D: It internalizes firm profits but also derives utility from e.g. consumer surplus and knowledge spillovers that the project creates:

$$U_i = V_i R_i + \Pi_i - g s_i R_i. \tag{3}$$

The first term on the right hand side captures the externalities (consumer surplus, informational spillovers to other firms, private agency (agent) benefits) which TTT calls agency specific (expected discounted) benefits as they are not captured by the firm. For brevity, we will call them spillovers in what follows. The second term captures firm profits and the third term captures the opportunity/shadow cost of public funds through the multiplier $g > 1$. We assume that the agency-specific benefits are linear in R&D and affected by observed firm and project characteristics Z_i and an unobservable (to the econometrician and the firm) shock η_i as follows: $V_i = Z_i\delta + \eta_i$. The shock η_i is the first dimension of the agency's type. Z_i includes the grades that the agency grants to project i (shocks - denoted ω_{ki} - to these are the two other dimensions of the agency's type). These (the "technical risk" and the "market risk") are the two main dimensions of the agency's grading process and we incorporate them into our analysis.

3.2 Estimation equations

The model generates the following main estimation equations:

1. The R&D investment equation:

$$lnR_i^* = X_i\beta - ln(1 - s_i) + \epsilon_i \tag{4}$$

with observation $lnR_i = d_i lnR_i^*$ where d_i is an indicator function taking the value one when firm i applies for subsidies for a given project and $exp(X_i\beta + \epsilon_i) = a_i$;

2. The agency decision rule:

$$s_i = Z_i\delta + (1 - g) + \eta_i \tag{5}$$

where Z_i are observable firm and project characteristics that affect the agency specific utility not appropriated by the firm, g is the opportunity cost of public funds, η_i is the agency's type, interpreted as the shock to agency specific utility and unobserved to the econometrician; and

3. The firm application decision

$$d_i = 1[exp(X_i\beta + \epsilon_i)[-E(ln(1 - s_i)) - K_i] \geq 0]$$

Besides these, the model generates two auxiliary equations that map the grades that the agency grants the project to observable firm characteristics.

4 Optimal policy reform

The equivalent of the optimal tax policy question (see e.g. Auerbach and Hines [2]) would be to introduce corporate taxes, subsidies and tax credits into the model and then optimize with respect to all of these. We will however take the existing corporate tax rate as given on the grounds that it is not determined purely from an innovation policy perspective and it is precisely the two other tools, subsidies and R&D tax credits, that allow the policy maker to tailor the environment so as to discriminate between innovative and other firms. We will therefore assume 1) that the existing regime of subsidies only is implemented optimally given the regime; 2) that the social planner can replace the R&D subsidies by R&D tax credits; and 3) that the social planner can optimize these. The question we pose is this: suppose the government decides to scrap R&D subsidies in favor of R&D tax credits and these have to be uniform across firms. What would the optimal R&D tax credit be?

4.1 TTT model with tax incentives

The first thing to note is that it is easy to show that R&D tax credits and R&D tax allowances amount to the same thing within our model. We therefore concentrate on tax credit. In our model the optimal level of R&D in a world of no innovation policy (or R&D subsidies only, the prevailing regime in Finland) is neutral with respect to the corporate tax rate τ which in Finland was 0.29 during our observation period 2000-2002 and is currently

0.26. Introducing corporate taxes and R&D tax credits into the above model changes the firm's objective function from a project to:

$$\Pi_i^E = (1-\tau)[\pi_i + a_i ln R_i - (1-\tau_c)R_i] \tag{6}$$

where τ is the corporate tax rate on profits and τ_c is what we call the R&D tax credit. It is related to the standard tax credit as follows: $\tau_{cstand} = \tau_c(1-\tau)$. We use this transformation as it is easier to work with and allows us to compare the optimal tax credit directly to the currently used subsidies. The optimal level of R&D in a tax credit regime is given by

$$R^{TC} = \frac{a_i}{1-\tau_c}. \tag{7}$$

Plugging this into Tekes' objective function and recalling that the social planner sums over all projects yields

$$U^{SP}(.) = \sum_i U^{SP}(R_i(\tau_c)) = \sum_i [V_i R_i(\tau_c) + \Pi_i^E(R_i(\tau_c)) - g\tau_c R_i(\tau_c)]. \tag{8}$$

Notice that in (8) it is assumed that other taxes that need to be used in order to keep tax receipts at the "old" level create a shadow cost of g. Therefore the shadow cost of the R&D tax credit is $g-1$. Solving this problem yields our

Proposition: *The optimal R&D tax credit is a negative function of the shadow cost of public funds and a positive function of agency specific returns to R&D.*

Proof: Optimizing (8) wrt to τ_c yields

$$\frac{\partial U^{SP}}{\partial \tau_c} = \sum_i [V_i \frac{\partial R_i}{\partial \tau_c} + \frac{d\pi}{dR_i}\frac{\partial R_i}{\partial \tau_c} + \frac{\partial \pi}{\partial \tau_c} - gR(\tau_c) - g\tau_c \frac{\partial R_i}{\partial \tau_c}] = 0.$$

Inserting (7), recalling that η_i, ω_{ki} (that affect V_i) and ϵ_i (which affects R_i) are independent, solving for τ_c yields the solution:

$$\tau_c^{TC} = \frac{\sum_i V_i a_i}{\sum_i a_i} + (1-g) \tag{9}$$

From (9) it is clear that the shadow cost of public funds $(g-1)$ affects the optimal R&D tax credit negatively. The agency specific benefits (spillovers) created by a given project are given by $V_i \frac{a_i}{1-\tau_c}$ and the equilibrium R&D investment by $\frac{a_i}{1-\tau_c}$, yielding the second claim of the proposition.

Q.E.D.

If one wanted to allow for firm specific tax credits, one would merely need to subscript τ_c and everything else with i. These would however pose informational requirements that are equally demanding as those in an R&D subsidy regime. The extensiveness of the currently used evaluation process precludes in our view the possibility of firm-specific R&D tax credits for the following reasons. One could use information similar to that obtained from our estimates to calculate "firm-specific" tax credits that depend only on observables, but neglect information in the shocks (as that information can only be obtained through a project-specific evaluation). While this may be feasible for a while, any shocks that affect all firms - say changes in EU's foreign trade policy - would render the used rules outdated. It also seems to be the case that the shocks are relatively important.

4.2 Laissez-faire benchmark

The benchmark we use for active policies is laissez-faire which we take to mean an environment with no government support for private R&D. The optimal level of R&D is then given by

$$R_i^{LF} = a_i, \tag{10}$$

and the laissez-faire levels of expected discounted profits and spillovers by $\Pi_i^{LF} = \pi_i + a_i[\ln a_i - 1]$ and $V_i a_i$.

5 Data

Our data comes from two sources. The project level data comes from Tekes, containing all applications to Tekes from January 1st 2000 to June 30th 2002. It consists of detailed information on the project proposals and Tekes' decisions. The firm level data comes from Statistics Finland. It combines information from the Business Register's enterprise-level data and the statistics on research and development. The Business Register data covers enterprises' addresses, branches of industry, size categories of personnel and turnover, dates of establishments and importer/exporter data. The data sources of the Business Register are several administrative records and Statistics Finland's direct inquiries to enterprises. Statistics on research and development (R&D panel) in turn contain data on e.g. R&D expenditure and funding, R&D personnel and R&D person-years. The statistics are based on data obtained from enterprises and are compiled according to the recommendations of the OECD and EU. The period covered is 1985-2005. We use all the firms in the R&D panel that have belonged to the survey at least once during the years 1997 - 2000. Firms that have not existed since 2000 have been excluded. Given that we treat our application period as a cross section we have constructed our covariates in the following way. First we have taken the information for 1999, if that was missing we have tried the 2000, 1998 and 1997 information respectively. Firm characteristics are thus recorded earlier than the subsidy decision.[3] After cleaning the data of firms with missing values, we are left with 6 910 firms. These firms constitute our sample of potential applicants and 1161 of them actually applied during our sample period. The firms in our sample account for roughly 60 percent of all applications. The average (median) number of applications per applicant firm in the sample is 2 (1).

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 heteroge-

[3] Even if we use the 2000 information for some firms, it is unlikely that the subsidy decision has affected the figures since there is a considerable lag between the application data and the subsidy decision date.

nous. They are on average 13 years old with 93 employees. A very high proportion of firms are SMEs according to the official EU standard. Sales per employee, a measure of value added, is 173 000 €. Almost half of the firms are exporters.

[TABLE 1 HERE]

From Table 2 we see that applicants are larger than non-applicants and successful applicants smaller than rejected ones. The median number of employees for non-applicants is 20, for applicants 24, and for rejected applicants 21. Quite naturally, applicants have more previous applications on average than non-applicants and the share of accpeted applications is also higher for the applicants.

Table 3 reports information about applications and Tekes' decisions (see TTT for more details). The application data we use in the estimations comprises 2193 applications. The average (median) number of applications per applicant firm in the sample is 2 (1). 399 firms had more than one application. 1641 of these applications were accepted, i.e. received a positive subsidy share. Some 25% of applications are rejected. The proposed projects involve on average an investment of 850 000 €, the rejected proposals being smaller with a mean of 320 000 €. According to Tekes' rating, the projects have on average a technical challenge of 2.3 (scale 0-5), and rejected proposals have on average a lower score of 1.7. The mean risk score is 2.1 and 2.2 for rejected applications.

[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 82% of applicants only apply for a subsidy, and 63% are only granted a subsidy, this seems a reasonable simplification. Measuring a subsidy in this way, X% of applicants get the maximum subsidy. Successful applicants receive on average a subsidy that covers 44% of the R&D investment costs. We test the robustness of our results to the definition of a subsidy by using only pure subsidies.

[TABLE 3 HERE]

6 Estimation results

We include into all estimation equations firm age, the log of the number of employees, sales per employee, a dummy for a parent company, a dummy for exporters, the number of previous applications, the share of accepted previous applications, the number of patents[4], a dummy for USPTO patents, R&D investment to sales ratio, R&D personnel per number of employees and personnel with university degree per number of employees. We also include industry and region dummies. The SME dummy is only included in the

[4]Our patent variable is the sum of Finnish patent applications, EPO patent applications and granted USPTO patents.

Tekes decision rule (15) and the application equation (13). We include it in (13) to allow for the possibility that SMEs' opportunity costs are different e.g. because of different access to other types of subsidies. Inclusion of the SME dummy in the application equation and exclusion of it from the R&D equation is sufficient for (nonparametric) identification. Our model yields additional identification through the expectation term in (13). In the reported specifications, we use a slightly different set of explanatory variables in the screening equations (11) and the Tekes decision rule (15) on the one hand, and the application and investment equations ((13) and (14)) on the other. For example, we include the squares of the continuous variables in application and investment equations ((13) and (14)). The results from the estimation of the screening equations (11) are reported in the Appendix. [ADD HERE: CROSS VALIDATION, SEMI-PARAMETRIC ESTIMATION, 99TH PCTILE ESTIMATION]

6.1 Tekes decision rule

In Table 4 we report the results concerning the Tekes decision rule. The coefficients can be interpreted as the marginal effects of R&D on spillovers. 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 almost 13 percentage point increase in the subsidy rate. Market risk carries a negative but insignificant coefficient. 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 8.7 percentage points. R&D investment to sales ratio and having USPTO patents have both a negative and significant effect on the subsidy rate. This means that Tekes considers the marginal effect of additional R&D investment on spillovers to be smaller in firms that are already actively engaged in R&D. [LISÄÄ TÄNNE] We relegate the industry and regional dummy-results to the Appendix.

[TABLE 4 HERE]

The above results are obtained under the assumptions that the error in the Tekes decision rule is uncorrelated with the errors in the investment and application equations. To test these assumptions, we first estimated a probit application equation and then re-estimated the Tekes decision rule by inserting the Mills ratio into it. The Mills ratio obtained imprecisely estimated coefficients with values close to zero in all of our several specifications, validating our assumptions of no correlation. Recall that this does not imply that spillovers are independent of profitability shocks, but rather that profitability shocks are transmitted to spillovers entirely through R&D. We also tested our assumption that V( ), the spillovers, is linear in the applicant's investment as implied by (7). 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. We included these and could not reject the Null of (joint) insignificance of them. The spillovers from a project seem thus to be linear in R&D. [ADD HERE: CLAD ESTIMATION RESULTS, ALTERNATIVE DEPENDENT VARIABLE]

6.2 Application cost function

[STATISTICAL SIGNIFICANCE BASED ON TTT, NO BOOTSTRAP RESULTS YET] In Table 5 we report the estimates of the application cost function. Sales per employee increase application costs. One interpretation is that firms producing high value added products and services 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. Exporters have lower costs, maybe because they are relatively more experienced in dealing with government bureaucracy than non-exporting firms.

[TABLE 5 HERE]

The share of accepted previous applications has a nonlinear effect, first decreasing and then, after 0.93, increasing application costs. The number of previous applications has a negative effect on the application costs that is increasing in the number of applications over the relevant range at a decreasing rate (until 230 applications). Increasing the number of past applications from non-applicants' median of zero to applicants' median of two decreases application costs by 9%. One prior application decreases costs by 5% and four by 18%. It seems that learning by doing is going on. Given that our data is cross sectional it is however possible that the results are generated by unobserved heterogeneity.

6.3 Investment function

[STATISTICAL SIGNIFICANCE BASED ON TTT, NO BOOTSTRAP RESULTS YET] This equation is often estimated in existing work on R&D subsidies: Our investment equation 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 and not surprisingly all the R&D variables have a positive (but decreasing) impact on marginal profitability of R&D investment. [ADD HERE: DIFFERENT SPECIFICATIONS, COEFFICIENT OF ln(1-s)]

[TABLE 6 HERE]

6.4 Covariance structure

We are able to identify the variances of all error terms, and the covariance between the unobservables in the application and investment equations (Table 7). The coefficient determining the variance share of investment shock in the application cost shock obtains a value of 1.012. The application cost shock and the investment shock are thus positively correlated. It could be that, similar to projects with higher sales per employee, projects with higher marginal profitability of R&D are more complicated involving tacit knowledge and are therefore more difficult to describe in an application. Or it could be that projects with higher marginal profitability of R&D have higher opportunity costs, which constitute a major part of application costs. However, the positive correlation is not reflected in the application decision since both the investment and application cost shocks affect the application decision cancelling out the correlation.

[TABLE 7 HERE]

7 Counterfactual calculations

The following regimes are compared: 1) no policy; 2) subsidies only (the prevailing regime in Finland); and 3) tax incentives only. We use our estimated parameter values and draw pseudorandom numbers (currently 1000) for the shocks from distributions with characteristics set to those implied by our estimated parameter values. We first use these simulation runs to calculate the optimal tax credit (τ_c) which turns out to be 0.234. Given the Finnish corporate tax of 0.29 during our observation period this translates into a (standard) tax credit (τ_{cstand}) of 0.166.

We then calculate the outcome variables of interest (R&D, spillovers (= agency specific benefits), profits, and welfare). We also calculate the out-of-pocket public sector expenditure on tax allowances and subsidies, and the application costs of firms for the subsidy regime [ALL THESE ARE NOT REPORTED YET].

[TABLE 8 HERE]

In Table 8 we compare active policies to the laissez-faire outcomes. We find that active policies generate significantly higher R&D investment than the laissez-faire: tax credit investments are 30% and R&D subsidy investments 20% higher than laissez-faire investment. At the same time, active policies produce private profits that are very close to the laissez-faire profit levels. The tax credit regime produces highest profits of the three, yielding 102% of the laissez-faire profits. In contrast, the spillovers that active policies generate are significantly above those of the laissez-faire world: now the subsidy regime fares best, producing 32% larger spillovers than laissez-faire. However, in terms of overall welfare, taking into account also the shadow cost of public funds, neither tax relief nor subsidies fare better than laissez-faire.

8 Robustness issues

8.1 Misreporting of R&D when tax incentives are used

An often heard objection to R&D tax credits is that firms engage in "innovative accounting" or "cost-padding", labeling as R&D something which isn't R&D. Our results suggest that while this may be a problem in practice, it will not change the welfare ranking of different policies as the tax allowance regime comes last even when this issue is assumed away.

8.2 Other issues

Our model assumes that firms and therefore projects are in Finland; this might not be the case if Finland went for laissez-faire. Brander and Spencer (1983) is the seminal paper analyzing strategic innovation policy, demonstrating the possibility that governments may find themselves in a Prisoner's dilemma. While Brander and Spencer do not consider "footloose" R&D, it is clear that allowing relocation of R&D would only strengthen the Prisoner's dilemma. We cannot therefore rule out that we underestimate the benefits of active innovation policy. [UPPER LIMITS FOR TAX RELIEFS, TARGETED TAX RELIEFS, SAME SHADOW COST OF PUBLIC FUNDS ASSUMED, VOLUME-BASED SUBSIDY...]

9 Actual policies vs. optimal policies in the OECD

OECD uses the so called B-index to compare the generosity of the tax treatment of R&D in different countries (for more details on the B-index see Warda, 2001). The B-index measures the after tax cost of one unit of R&D expenditure divided by one minus the corporate income tax rate. The rate of tax subsidy is in turn measured as 1 minus the B-index. Figure 1 shows how our result is positioned in the OECD statistic describing the actual rate of tax subisides in various countries. Our estimate of a tax credit of 16 % yields a 0.23 rate of tax subsidy. This is somewhat above the average tax subsidy, which is 0.19 for SMEs and 0.18 for large firms, but well below the largest tax subsidies of 0.39 and 0.37 in Spain and in Mexico respectively.

[FIGURE 1 HERE]

What is clear from our model is that the crucial issue in determining the optimal level of an R&D tax credit is the level of spillovers. Whilst impossible to prove within our model, it is our view that the low level of spillovers relative to private profits that we estimate is due to the structure of the Finnish economy. Finland is a small open economy whose population amounts to 0.01% of world population and whose R&D is roughly 1% of global R&D. It is therefore very plausible that a very good idea in terms of an idea's capacity to generate expected discounted profits is one that generates revenues primarily outside Finland. As the Finnish social planner only internalizes Finnish consumer surplus and spillovers to other domestic firms, these can (and seem to) be significantly lower than the private profits which the Finnish social planner completely internalizes.

If this is the right interpretation, it would mean that keeping everything else the same, larger countries than Finland should have optimal R&D tax credits that are higher than those in Finland, and smaller countries lower ones. However, Figure 1 does not provide support for this argument. There does not seem to be systematic differences in the tax incentives for R&D between large and small countries.

10 Conclusions

The objective of this paper was to analyze a reform in innovation policy - the introduction of R&D tax credits - that has either been undertaken, or is being considered, by many industrialized countries. To achieve this objective, we solve a structural model for the optimal R&D tax credit, and use our parameter estimates to calculate the effects of the policy change. For purposes of comparison, we not only compare the actual policy of R&D subsidies only to that of an R&D tax credit - only regime, but also compare the outcomes generated by these two policies to what would have been achieved under laissez-faire. A benefit of our approach is that we first uncover the policy makers preferences from implementing the actual (R&D subsidy) policy, and then keep them constant when we change policies. A fundamental assumption of our approach is thus that the observed policy actions are based on optimizing behavior.

We find that the optimal R&D tax credit in Finland is 17%. Transforming this into tax subsidy using the OECD B-index yields a tax subsidy of 0.23. This means that one unit of R&D expenditure results in 0.23 unit of tax relief. We also find that private profits dominate spillovers. The most likely explanation for this is that Finland is a small open economy and therefore most of the consumer surplus and knowledge spillovers that Finnish R&D generates lie outside Finnish borders and are therefore not internalized by Finnish policy makers. This line of reasoning would suggest that the optimal Finnish R&D tax credit should be lower than in an otherwise similar but larger country.

When comparing the outcomes in the different policy regimes we find that optimal R&D tax credits and current R&D subsidies produce higher levels of R&D and spillovers than laissez-faire. However, in terms of private profits active policies fare only slighter better compared to laissez-faire and once we take into account the shadow cost of public funds to calculate overall welfare all the three regimes amount to the same.

References

[1] Abbring, J. & Heckman, J. (2008): Dynamic policy analysis, CeMMAP working papers CWP05/08, Centre for Microdata Methods and Practice, Institute for Fiscal Studies.

[2] Auerbach, A., and Hines, J., 2002, Taxation and Economic Efficiency, in A. Auerbach and M. Feldstein, eds., Handbook of Public Economics, vol. 3., 1347-1421.

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

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

[5] Heckman, J. J. and E. J. Vytlacil (2007a): Econometric evaluation of social programs, part I: Causal models, structural models and econometric policy evaluation. In J. Heckman and E. Leamer (Eds.), Handbook of Econometrics, Volume 6B, pp. 4779–4874. Amsterdam: Elsevier.

[6] Heckman, J. J. and E. J. Vytlacil (2007b). Econometric evaluation of social programs, part II: Using the marginal treatment effect to organize alternative economic estimators to evaluate social programs and to forecast their effects in new environments. In J. Heckman and E. Leamer (Eds.), Handbook of Econometrics, Volume 6B, pp. 4875–5144. Amsterdam: Elsevier.

[7] Jones, C., and Williams, J. (1998): Measuring the social return to R&D, Quarterly Journal of Economics, 113, 4, 1119-1135.

[8] Moen, J.. and Haegeland, T.(2007): Do the Norwegian R&D tax credit increase R&D investments?, mimeo, NHH.

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

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

[11] Takalo, Tanyama and Toivanen (2008): Evaluating innovation policy: a structural treatment effect model of R&D subsidies, Research Discussion Papers, Bank of Finland 7/2008.

[12] Trajtenberg, M. (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.

[13] Warda, 2006

Table 1
Descriptive Statistics

	Mean	S.d.	Min.	Max.
Age, years	13	12	0	97
# Employees	93	475	0	21391
Sales per employee, 1000€	173	502	0	1.84 E-07
SME dummy	0.92	0.27	0	1
Parent dummy	0.07	0.26	0	1
Exporter dummy	0.48	0.5	0	1
# past Tekes applications	1.4	6.8	0	276
Share of accepted past Tekes applications	0.32	0.45	0	1
# past patents	2.9	49.3	0	2951
USPTO patents dummy	0.05	0.21	0	1
R&D investment / sales ratio	0.53	10.2	0	482
R&D personnel / employees ratio	0.22	0.84	0	1
Personnel with university degree / employees ratio	0.16	0.3	0	1
Applicant	0.17	0.37	0	1

NOTES: There are 6910 firms. Data sources: Statistics Finland otherwise; for data on applications, Tekes.

Table 2
Conditional Descriptive Statistics

	Non-Applicants	Applicants	Rejected Applicants	Successful Applicants
Age	14 (12) [11]	11 (11) [8]	11 (11) [8]	11 (10) [8]
# Employees	69 (354) [20]	213 (840) [24]	239 (943) [21]	203 (800) [25]
Sales per employee, 1000€	177 (535) [94]	154 (290) [99.9]	146 (333) [96]	157 (273) [101]
SME dummy	0.94 (0.24)	0.83 (0.37)	0.81 (0.39)	0.84 (0.36)
Parent company dummy	0.06 (0.24)	0.14 (0.34)	0.12 (0.32)	0.14 (0.35)
Exporter dummy	0.45 (0.50)	0.61 (0.49)	0.55 (0.50)	0.63 (0.48)
# past Tekes applications	0.65 (2.15) [0]	4.93 (15.43) [2]	4.78 (15.20) [1]	4.99 (15.52) [2]
Share of accepted past Tekes applications	0.25 (0.43) [0]	0.67 (0.44) [1]	0.6 (0.46) [.93]	0.7 (0.43) [1]
# past patents	1.27 (31.51) [0]	10.69 (97.24) [0]	15.03 (171.04) [0]	9.16 (49.80) [0]
USPTO patents dummy	0.03 (0.17)	0.13 (0.34)	0.11 (0.31)	0.14 (0.34)
R&D investment / sales ratio	0.28 (7.09) [0]	1.78 (19.19) [0.03]	1.53 (15.87) [0.01]	1.87 (20.25) [0.03]
R&D personnel / employees ratio	0.18 (0.83) [0]	0.44 (0.85) [0.13]	0.41 (0.90) [0.08]	0.45 (0.84) [0.15]
Personnel with university degree / employees ratio	0.12 (0.27) [0]	0.34 (0.34) [0.25]	0.3 (0.34) [0.2]	0.35 (0.34) [0.29]
Nobs. (firms)	5749	1161	303	858

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

Table 3
Descriptive Statistics of Tekes and Application Variables

	All Applications	Successful Applications	Rejected Applications
Applied amount, €	395 108	430 867	288 802
	(724 223)	(763 353)	(580 576)
Applied for subsidy only	0.82	0.82	0.83
	(0.38)	(0.38)	(0.38)
Technical challenge	2.3	2.56	1.67
	(1.02)	(0.88)	(1.07)
	{1524}	{1085}	{439}
Risk	2.14	2.13	2.17
	(1.02)	(0.99)	(1.09)
	{1129}	{822}	{307}
Granted subsidy rate	-	0.44	-
		(0.10)	
Granted subsidy only	-	0.63	-
		(0.48)	
Nobs. (Applications)	2193	1641	552

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	Dep. var. subsidy-intensity (all finance)
Risk	-.006 [-.024 .012]
Challenge	.127*** [.107 .146]
Age	.002* [-.00007 .003]
# Employees	-.014* [-.029 .002]
Sales per employee, 1000€	.00005 [-.00003 .0001]
SME dummy	.087** [.020 .155]
Parent company dummy	-.050* [-.102 .003]
Exporter dummy	.019 [-.030 .069]
# past Tekes applications	.0004 [-.0002 .001]
Share of accepted past Tekes applications	.069*** [.019 .118]
# past patents	-.00007 [-.0002 .0001]
USPTO patents dummy	-.079*** [-.133 -.025]
R&D investment / sales ratio	-.001*** [-.002 -.0006]
R&D personnel / employees ratio	.011 [-.09 .032]
Personnel with university degree / employees ratio	-.012 [-.069 .045]
Constant	-.046 [-.186 .094]
INDUSTRY DUMMIES	YES
REGIONAL DUMMIES	YES
σ_η	.265*** [.250 .280]
Nobs.	1058

Table 5

Application Cost Function Results

Variable	Coefficient [95 % confidence interval]
Age	.005 [ ]
Age sq.	.-00009 [ ]
ln(employees)	.076 [ ]
ln(employees) sq.	-.008 [ ]
Sales per employee, 1000€	8.00E-04 [ ]
Sales per employee sq.	-9.54E-11 [ ]
Parent company dummy	-.127 [ ]
Exporter dummy	-.015 [ ]
SME dummy	.313 [ ]
# past Tekes applications	-.046 [ ]
# past Tekes applications sq.	.00010 [ ]
Share of accepted past Tekes applications	-2.135 [ ]
Share of accepted past Tekes applications sq.	2.287 [ ]
# past patents	.003 [ ]
# past patents sq.	-8.71E-07 [ ]
USPTO patents dummy	.0005 [ ]
R&D investment / sales ratio	.004 [ ]
R&D investment / sales ratio sq.	-7.04E-06 [ ]
R&D personnel / employees ratio	.078 [ ]
R&D personnel / employees ratio sq.	-.007 [ ]
Personnel with university degree / employees ratio	-.726 [ ]
Personnel with university degree / employees ratio sq.	.748 [ ]
Constant	10.468 [ ]
INDUSTRY DUMMIES	YES
REGIONAL DUMMIES	YES
Nobs	7958

Table 6
R&D Investment Function Results

Variable	Coefficient [95 % confidence interval]
Age	-.021 [ ]
Age sq.	.0002 [ ]
ln(employees)	.178 [ ]
ln(employees) sq.	-.009 [ ]
Sales per employee, 1000€	.0005 [ ]
Sales per employee sq.	-8.08E-08 [ ]
Parent company dummy	.270 [ ]
Exporter dummy	.006 [ ]
# past Tekes applications	.002 [ ]
# past Tekes applications sq.	-.00002 [ ]
Share of accepted past Tekes applications	-1.091 [ ]
Share of accepted past Tekes applications sq.	1.310 [ ]
# past patents	.002 [ ]
# past patents sq.	-8.64E-07 [ ]
USPTO patents dummy	.304 [ ]
R&D investment / sales ratio	.014 [ ]
R&D investment / sales ratio sq.	-.00002 [ ]
R&D personnel / employees ratio	.296 [ ]
R&D personnel / employees ratio sq.	-.033 [ ]
Personnel with university degree / employees ratio	.626 [ ]
Personnel with university degree / employees ratio sq.	-.425 [ ]
Constant	10.926 [ ]
INDUSTRY DUMMIES	YES
REGIONAL DUMMIES	YES
Nobs	2193

Table 7

Covariance Structure Results

Variable	Coefficient [95 % confidence interval]
Standard deviation of the investment equation shock, σ_ε	1.054 [ ]
Standard deviation of the Tekes specific utility (=V( )) shock, σ_η	.265*** [.250 .280]
Standard deviation of the uncorrelated part of the application cost function shock, $\sigma_{\nu 0}$	0.69 [ ]
Measure of the variance share of ε in ν, (1+ρ)	1.012 [ ]
Correlation between ε and the application equation error term	-0.018 [ ]

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.

Table 8

Outcome of simulations as percentage of laissez-faire outcome

Policy regime	Outcome measures			
	R&D investment	Profits	Externalities	Social benefit
Tax relief	130 %	102 %	130 %	100 %
Subsidy	120 %	101 %	132 %	100 %

Figure 1: Our estimated tax subsidy and actual tax subsidies in 2007 (OECD Science, Technology and Industry Scoreboard 2007)