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Impact of Swiss technology policy on firm innovation performance: an evaluation based on a matching approach

Spyros Arvanitis, Laurent Donzé and Nora Sydow

This paper investigates the impact of the promotional activities of the Swiss Commission of Technology and Innovation (CTI) on the innovation performance of the supported firms based on a matched-pairs analysis of 199 firms supported by the CTI in the period 2000–2002. CTI's promotional activities significantly improved the innovation performance of the firms that they supported with respect to six different measures of innovation performance. This could be shown by four different matching methods. A further finding was that the magnitude of the impact correlated positively with the relative size of the financial support, as measured by the quotient of the volume of financial support to the volume of a supported firm's own research and development expenditures.

THE IMPACT OF THE INNOVATION promotion policy of the 'Commission of Technology and Innovation' (CTI), which is the most important government agency for the promotion of innovation in Switzerland, was investigated in this study. The CTI mainly supports research and development (R&D) co-operation projects from all scientific fields by funding the public partner (a university or a public research institution) in such a co-operation, the private partner being an enterprise that agrees to contribute to this project at its own expense by at least the amount of funds offered by the CTI (private contribution of at least 50%; the 'bottom-up' principle of support). The projects to be subsidized are selected by committees of experts that evaluate the applications by some criteria of excellence. There have also been some recent programmes for the promotion of specific technologies (e.g. MedTech, TopNano21), but this type of specific support has always been of minor importance. The principle of indirect R&D support of good projects, which are jointly proposed by a private and a public partner, is fundamental to the Swiss technology policy and, as a main promotional policy, to our knowledge, is unique in Europe.

Our main hypothesis was that: on average enterprises that were supported by the CTI would show a significantly higher innovation performance, measured through six innovation measures (e.g. sales, share of innovative products), than 'structurally similar' firms without such activities. To show this, we used matched-pairs analysis for a set of firms supported by CTI and the corresponding control groups for the period 2002–2004.

Matching methods based on direct comparisons of participating and non-participating agents, which were first used in labour market evaluations, have also been applied to evaluate the technology programmes of European countries (see Almus and Czarnitzki, 2003; Czarnitzki and Fier, 2002 (for Germany); Pointner and Rammer, 2005 (for Austria); Görg and Strobl, 2007 (for Ireland)).[1] A major advantage of the matching methods rather than the regression approach is that the matching is non-parametric. As such, it

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avoids the functional form restrictions implicit in running a regression of some type.

A brief description of the approach pursued in this paper is as follows: we identified the subsidized firms in the period 2000–2002 from the CTI database. We collected innovation data for the promoted firms similar to those already existing for a sample of innovating firms of the Swiss Innovation Survey 2002 (Arvanitis *et al*., 2004). We estimated the propensity scores with respect to the likelihood of receiving a CTI subsidy. We then applied four different matching methods in order to find the structurally similar 'twin' firms for every subsidized firm. We tested the statistical significance of the difference of the means of six different innovation measures of the subsidized firms and the non-subsidized firms of the matched control group. We constructed a subsidy quotient: the amount of R&D promotion divided by the R&D budget of the firm in the same period. We were able to distinguish between firms with a high (higher than the median) and a low subsidy quotient (lower than the median), and carry out a statistical test on the difference of the differences of the means of the innovation variables of the subsidized firms and the matched non-subsidized firms.

For the period 2002–2004 we found that (with one exception), for all six innovation measures and for all four matching methods applied, the innovation performance of CTI-subsidized firms was on average significantly higher than that of the non-subsidized firms in the matched control group. Further, it was shown that the promotion effect was (with one exception) dependent on the magnitude of the promotion ratio (as measured by the ratio of R&D subsidies by CTI to a firm's own R&D expenditure).

The new elements in our analysis were:

- the use of innovation data for the subsidized firms, collected by means of a survey;
- the use of four different matching methods that allowed us to test the robustness of our results; and
- the investigation of the effect of promotion ratio as measured by the ratio of R&D subsidies by CTI to a firm's own R&D expenditure.

The paper is structured as follows: first, we present the conceptual framework of the study; secondly, we give an overview of similar studies. Thirdly, we deal with the data sources; fourthly, we present some information on the patterns of CTI promotion in the reference period. Fifthly, we provide a detailed discussion of our methodology for estimating the impact of CTI subsidies on the innovation performance of firms. We then discuss the results and provide a summary and some implications for technology policy.

Conceptual framework

Technology policy: public fiscal policies to support innovation

Most OECD countries use large amounts of public funds to support activities that are intended to enhance innovation in the business sector. These funds are often used to provide direct support for private sector research and innovation. A further way of supporting private investment in innovation is through tax incentives for R&D expenditures (see Jaumotte and Pain, 2005 for a survey of the main fiscal policies to support innovation). The underlying justification for public policies to support innovation is provided by the economic argument that otherwise the private sector would invest less in innovative activities than is socially desirable. The reasons for such 'market failure' that leads to underinvestment in innovative activities could be: informational imperfections, informational externalities due to knowledge spillovers, financial market failures or shortages of highly qualified personnel (Nelson, 1959; Arrow, 1962). Thus, public fiscal policies to support innovation are designed to alleviate particular forms of market failure that would lead to under-investment. For example, programmes offering financial support for small or young firms are intended to stimulate additional R&D and innovation in firms that would otherwise have difficulty funding themselves in the capital market. In practice, identifying the firm or project categories that should be subsidized requires difficult judgements to be made.

Swiss technology policy

There is a long tradition in Switzerland of refraining from directly funding business firms for innovation activities. In a comparison of industrialized countries only Japan and Luxembourg show a comparably low percentage of government financing for R&D (OECD, 2007). This tradition is based on a wide consensus not only among political actors but also among organizations representing business interests. According to the results of the Swiss Economic Survey (Arvanitis *et al*., 2007), less than 10% of Swiss firms perceive a lack of public R&D promotion to be a strong, or very strong, obstacle to their innovation activities; this percentage has remained practically constant since 1990. As a consequence, only a few fiscal initiatives to support research and innovation at firm level have been launched in recent years. CTI is the government agency through which public funds are poured into the business sector. Besides the promotion of entrepreneurship through CTI's start-up funding programme plus a mobilization initiative called Venturelab, most of CTI funds are directed to financing 'bottom-up'-initiated R&D projects from all scientific fields, CTI supporting the academic partner of the project. There have also been programmes for the promotion of specific technologies (e.g. MedTech, TopNano21) but this kind of specific support has always been of minor importance. The principle of indirect R&D support of good projects, which are jointly proposed by a private and a public partner, is fundamental to Swiss technology policy. To the best of our knowledge, it is unique in Europe as a main promotional policy.[2]

Methods of evaluation of measures of technology policy

Evaluating the outcomes of subsidized projects is difficult, both because of the difficulties in estimating the wider social benefits that they generate and because of the difficulties in assessing what the 'counter-factual' would have been in the absence of public support. Typically, evaluations of outcomes, i.e. estimations of the impact of policy, proceed by means of an *ex post* assessment of the activities of the firms that have received subsidies. Such evaluations can be subject to selection-bias problems because subsidized firms are *not* a random group. They are mostly selected because of the high quality of the proposed projects, that is, those projects that are the best candidates for funding are also the projects that would have the largest expected output in the absence of funding.

The principle of indirect R&D support of good projects, which are jointly proposed by a private and a public partner, is fundamental to Swiss technology policy. To the best of our knowledge, it is unique in Europe as a main promotional policy

There are several empirical strategies for mitigating selection bias in the *ex post* evaluations, e.g. regression with controls for unobserved effects; regression with fixed effects or 'difference in differences'; selection models and matching methods based on direct comparisons of the participating and non-participating agents, i.e. on matched samples of treated and untreated entities (Klette *et al.,* 2000; Jaffe, 2002; Arvanitis and Keilbach, 2002).

In this study we apply matching methods to evaluate the impact of R&D subsidies on the innovation performance of subsidized firms. A major advantage of the matching methods over the regression approach is that the matching is non-parametric. As such, it avoids the functional form restrictions implicit in running a regression of some kind. Of course, this method also has shortcomings. First, a close similarity with respect to all observable characteristics that are believed to be correlated with the likelihood that a firm or a project would be selected for subsidies may fail to control fully for any selection bias, given that in most cases only a restricted dataset of firm characteristics is available. Secondly, due to a lack of information, potential knowledge spillovers are not taken into consideration (this also happens when regressions are run). Theoretically, the only set-up for a support measure in order to avoid *ex ante* selection bias would be to undertake an evaluation by awarding grants (subsidies) randomly within a pool of actors who are judged suitable for funding (Jaffe, 2002). But such a random mechanism for distributing subsidies also raises the issue of whether or not the social welfare would be lower if some projects with a high potential go without funding.

Empirical evidence on the effectiveness of technology policy

Recent overviews of the empirical literature suggest that the empirical evidence as to the effectiveness of subsidies is not homogeneous (David *et al*., 2000; Hall and Van Reenen, 2000; Klette *et al*., 2000; Jaumotte and Pain, 2005), a finding also confirmed by the meta-analysis by Garcia-Quevado (2004) which was based on the results of 39 studies of the effectiveness of public subsidies. All overviews emphasize the importance of the control variables included in any empirical assessment and the level of aggregation at which a study is conducted. Differences with respect to these two factors seem to explain a large part of the differences found between empirical studies. Thus, for the assessment of a study, it is necessary to take these two factors into consideration.

Summary of similar studies

In this section of the paper, we review studies at firm level that aim to measure the impact of public fiscal support on some performance measure and apply either matching approaches (as in this paper) or selection correction approaches. Most studies use contemporaneous data on the states of subsidized and non-subsidized firms (as in this paper). Table 1 presents a summary of such studies. Seven of them refer to European countries (Austria, Germany, Ireland, Spain and Switzerland), six of them apply matching approaches and one of them only uses a selection correction approach. Moreover, the study for Ireland combines selection correction approach and matching method, that for Austria uses both approaches. Finally, three of the non-European studies (USA, Japan and Israel) use versions of the selection correction method, while the Canadian study is based on a matching approach and is the only study that compares the impact of two different policy instruments. Six out of ten studies use R&D intensity, R&D expenditure or R&D personnel as the target variables of the promotional measures. For one study the target variable is innovation expenditure. The Canadian study uses eight different output-oriented innovation measures as target variables. Finally, in three studies some technology diffusion measure is chosen as the goal variable. Most studies

Table 1. Summary of selected empirical studies

Study/country	Policy instrument being evaluated	Number of firms	Approach	Impact on target variable
Sakakibara (1997), Japan	Government-sponsored co-operative R&D projects organized by Ministry of International Trade and Industry (1983–1989)	226	Selection correction: Two-equation system (participation eqn., R&D effort eqn.)	R&D spending: + Patents: +
Busom (2000), Spain	R&D subsidy programme 1988	154	Selection correction: Two-equation system (participation eqn.: R&D effort eqn., patent eqn.)	R&D expenditures: R&D personnel, R&D expenditures/sales, R&D personnel/employment: +
Wallsten (2000), USA	Small Business Innovation Research (SBIR) Programme (1990–1992)	81	Selection correction: Three-equation system (two different participation eqns.: R&D spending eqn., employment eqn.)	R&D spending 1992: − employment 1993: no effect
Arvanitis *et al*. (2002), Switzerland	Programme of promoting use of Computer Integrated Manufacturing Technologies (CIMT) (CIM Programme, 1990–1996)	463	Selection correction: Two-equation system (participation eqn., CIMT adoption eqn.)	Change in CIMT intensity (1990–1996): + for firms with less than 200 employees + for firms adopting CIMT for first time
Donzé (2002), Switzerland	Programme of promoting use of CIMT (CIM Programme, 1990–1996)	463	Matched-pair analysis (several alternative methods)	Change in CIMT intensity (1990–1996): + for firms with less than 200 employees + for firms adopting CIMT for first time
Lach (2002), Israel	R&D grants from Office of Chief Scientist at Ministry of Industry and Trade (1990–1995)	325	Difference-in-difference estimator	R&D spending: + for small firms no effect for large firms
Czarnitzki and Fier (2002), Germany	Public innovation subsidies in German service sector	210	Matched-pairs analysis (nearest neighbour matching)	Innovation expenditure: innovation expenditure/sales: +
Almus and Czarnitzki (2003), Germany	R&D subsidies to East German firms (1994, 1996, 1999)	622	Matched-pairs analysis (calliper matching)	R&D intensity: +
Pointner and Rammer (2005), Austria	Programme of promoting use of CIMT (FlexCIM Programme, 1991–1996)	301	(a) Selection correction: Two-equation system (participation eqn.: CIMT-adoption eqn.) (b) matched-pair analysis	Change in CIMT intensity (1992–1998): + for firms with less than 200 employees + for firms with low intensity of CIMT use
Görg andStrobl (2007), Ireland	R&D grants from (Industrial Development Agency (IDA) Ireland and Forbairt (1999–2002)	828	Combination of matching approach and difference-in-difference estimator	R&D spending; R&D spending per employee: small domestic firms: + medium domestic firms: no effect; large domestic effects: − all size classes of foreign firms: no effect
Bérubé and Mohnen (2007), Canada	R&D tax credits *versus* R&D tax credits + R&D grants	584	Matched-pairs analysis (nearest neighbour matching)	Firms with tax credits + R&D grants are *more* innovative than firms with only tax credits for 6 out of 8 innovation indicators

Notes: + (−): positive (negative) and statistically significant effect at 10% test level find a positive policy effect but in some cases only for small firms. The USA study is the only one, which finds a negative effect for R&D spending, meaning that subsidies were crowding out private R&D spending. Although all the studies in Table 1 refer to the firm as the analytical entity, a closer comparison of the results of these studies is not possible due to large differences with respect to the variables taken into consideration in order to control for selection bias.

Database

Our information sources were:

- a list of the firm projects that were subsidized by the CTI in the period 2000–2002;
- additional information on the firms whose projects were subsidized that was collected through a survey of the subsidized firms based on a shortened version of the questionnaire used in the Swiss Innovation Survey 2002; and
- the data for firms that reported the introduction of innovations in the period 2000–2002 in the Swiss Innovation Survey 2002.

The CTI database contained information on 634 subsidized R&D projects that were finished between 1 January 2000 and 31 December 2002. There was information on the scientific field of the project, the amount of the subsidy granted, and the name and address of the enterprises that conducted the subsidized projects. These firms made up our sample of subsidized firms. Start-ups, non-profit organizations and mergers were excluded from this sample because their specific characteristics could be not identified in our pool of control firms. Further, firms that had ceased to exist by December 2003 were also removed from the sample. The final sample contained 307 subsidized firms. These firms received a shortened version of the questionnaire of the Swiss Innovation Survey 2002.[3] 185 firms completed the questionnaire (see Table A1 in the Appendix to this paper for information on the response rates by scientific field). A further 14 subsidized firms were identified among the participants of the Swiss Innovation Survey 2002. Hence, the sample we used for the study contained data on 199 firms (64.8% of the subsidized firms). Additional information on the determinants of the propensity scores (see section on Method) was collected through a telephone survey of the 122 subsidized firms that did not complete the postal survey. This additional information allowed us to estimate the propensity scores based on data for all 307 subsidized firms.

The 996 firms that participated in the Swiss Innovation Survey 2002 and reported the introduction of innovations in the period 2000–2002 built the pool of non-subsidized firms from which a control group was constructed (KOF panel database).

For the firms that finished their projects subsidized by the CTI during the first half of the period 2000–2002, i.e. until the middle of 2001, we reckon that they would still have had one-and-a-half years until the end of the reference period to realize some impact of these projects on their innovation performance (e.g. introduce new products); one-and-a-half years is an adequate time lag between R&D and realization of R&D outcomes for most industries and for incremental innovations. For the firms that completed their subsidized R&D during the second half of the reference period, particularly in the year 2002, it is questionable, whether or not they would have had enough time until the end of 2002 to realize any additional innovation gains. 53% of projects were finished by the middle of 2001, 78% by the end of 2001. Hence, for the large majority of the projects there was enough time to have a measurable impact of R&D on their innovation performance. For the remaining 28% of the firms, it is possible that only part of the impact could be realized before the end of 2002. In this sense our estimations of the impact of CTI promotion would thus represent a lower bound on the possible effects.

Patterns of CTI promotion in period 2000–2002

As already mentioned, in the period 2000–2002 634 R&D projects were supported by the CTI. Table 2 shows the scientific fields in which these projects were located and the amount of the subsidies granted by scientific field. The projects in the fields of machinery and apparatus construction as well as information technology (software) amounted to about 33% of all projects and also received about 33% of the total subsidies. In general, the subsidies were rather broadly distributed among several scientific fields, which was in accordance with the general promotion policy of the CTI, based mainly on the 'bottom-up' principle of support. So-called future-oriented technologies such as biotechnology (3.6% of projects, 4.5% of subsidies) and nanotechnology (5.7% of projects, 3.8% of subsidies) do not seem to have been particularly promoted. In total, about 120 million Swiss francs (CHF) were invested in projects promoted by the CTI, i.e. CHF60 million per annum. The mean subsidy per project was CHF190,000. The mean amounts among scientific fields varied between CHF167,000 for information technology and CHF267,000 for microelectronics. This means that including the firms' contribution of at least the same amount as the CTI subsidy, about CHF400,000 was invested per project.

Table 3 shows the distribution of subsidies among firms by scientific field. Enterprises with more than one project were classified by the scientific field of the project with the highest subsidy. The share of firms with projects in machinery, apparatus construction and information technology is about 22%,

Table 2. Subsidized projects and volume of subsidy by scientific field 2000–2002

Scientific field	Number of projects	Percentage	CTI subsidy (in CHF (Swiss francs))	Percentage	CTI subsidy per project (in CHF)
Construction technology	27	4.3	3,801,686	3.1	140,803
Biology	23	3.6	5,462,365	4.5	237,494
Electrical machinery/electronics	32	5.0	6,477,776	5.4	202,431
Information technology	103	16.2	17,235,837	14.3	167,338
Machinery, construction of apparatus	105	16.6	22,735,819	18.8	216,532
Material sciences	56	8.8	13,992,873	11.6	249,873
Microelectronics	48	7.6	12,810,767	10.6	266,891
Nanotechnology	36	5.7	4,537,160	3.8	126,032
Process engineering	41	6.5	8,761,137	7.2	213,686
Production/management concepts	51	8.0	8,406,303	7.0	164,829
Other	112	17.7	16,631,768	13.8	148,498
Total	634	100.0	120,853,491	100.0	190,621

Source: CTI database, authors' calculations

significantly lower than the respective share of projects of these scientific fields. In contrast, material sciences are better represented among firms (about 24%) than among projects (about 12%).

The subsidized firms are further characterized by the industry affiliation and the number of employees in full-time equivalents (firm size). 52% of promoted firms belonged to mechanical and electrical machinery, electronics and instruments. This was the dominant group among subsidized firms in accordance with the importance of these capital goods industries for Swiss manufacturing with respect to generated value added, employment and innovativeness, even if it is rather over-represented. Chemical and pharmaceutical firms, which are on average the most innovative Swiss firms, are quite under-represented among the subsidized firms (4%), reflecting the strong tendency of this branch of above-average investment in R&D. With the exception of wholesale trade the service sector is represented in the sample of the subsidized firms only by business services (computer services, engineering, business consulting, etc., about 21%). Small firms with up to 50 employees have a share of about 55%, firms with more than 200 employees a share of only about 25%, firms with more than 500 employees a share of about 10%.

Both the distribution among industries and among firm size classes seem to be in accordance with the policy pursued by the CTI of promoting mainly small- and medium-sized enterprises in all sections of the economy; there is even a tendency to promote small- rather than medium-sized firms.

Table 3. Subsidized enterprises by scientific field 2000–2002

Scientific field	Number of firms	Percentage
Construction technology	11	5.5
Biology	7	3.5
Electrical machinery/electronics	12	6.0
Information technology	21	10.6
Machinery, construction of apparatus	23	11.6
Material sciences	48	24.1
Microelectronics	21	10.6
Nanotechnology	6	3.0
Process engineering	16	8.0
Production/management concepts	14	7.0
Other	20	10.1
Total	199	100.0

Notes: Enterprises with more than one project were classified by scientific field of project with highest subsidy
Source: CTI database, authors' calculations

Method

Our main hypothesis is that the CTI support, particularly through co-financed research projects in co-operation with universities, would show on average a significantly higher innovation performance, as measured by output innovation measures (e.g. sales share of innovative products), than 'structural similar' firms without such activities. We used several matching methods to demonstrate this.

In order to measure appropriately the influence of CTI subsidies on a firm's innovation performance ('treatment effect')[4] we should be able to measure the performance difference of the two 'states' of a firm (subsidized by the CTI ('treated')/ non-subsidized by the CTI ('non-treated')), keeping all other things equal. In a cross-sectional framework, usually only one of these two possible states is observable: either a firm is subsidized *or* it is not subsidized. Thus, in most cases it is not possible to make a proper comparison of these states. Heckman *et al*. (1998) developed a methodology to approximate this non-observable ('counterfactual') state of a certain firm with the observable same state of another firm which is 'structurally similar' to the first one according to a series of firm characteristics formally defined by a vector X. Thus, besides the group of firms, which are subsidized by CTI in a certain time period, we need a pool of firms which are not subsidized out of which 'structurally similar' firms are selected according to a 'proximity' criterion (control group). The comparison of the two states for subsidized and non-subsidized firms is performed by comparing the means of the innovation performance variables for the 'treated' firms and the 'twin' 'non-treated' firms matched to the 'treated' ones according to a proximity criterion. The multi-dimensionality of the matching problem (matching with respect to each single element of a vector X of firm characteristics) can be reduced under certain conditions (Rosenbaum and Rubin, 1983) to a mono-dimensional (scalar) propensity score which comprehends the entire information of all relevant characteristics.[5]

The state of a firm belonging to the group of the 'treated' firms is described by $d = 1$, the state of a 'non-treated' firm by $d = 0$. If Y_{1i} is a vector of innovation measures for the treated firm i [$i \in (d = 1)$] and Y_{0i} the corresponding vector for a firm j belonging to the control group [$j \in (d = 0)$], which is the 'twin' firm to firm i, then the performance difference between the two firms is defined as:

$$\Delta Y = Y_{1i} - Y_{0i} \quad (1)$$

In a first step we estimated by a probit model the propensity scores $P(X)$, i.e. we estimated the probability of a firm having a research project subsidized by the CTI as a function of a vector X of firm characteristics As independent variables X we used: a variable characterizing a firm's R&D activities (continuous vs. occasional), the degree of exposure to international competition (export activities yes/no), age of firm ('firm founded before 1996'), size of firm (dummy variables for six size classes), industry affiliation (dummy variables for three sub-sectors), geographical location (dummy variables for six geographical regions) and language of the questionnaire (see Table A2 in the Appendix to this paper for the results of the probit estimates).

In a second step all firms were distributed to adjustment cells according to the quintiles of the propensity scores estimated by the equation in Table A2. The search for a 'twin' firm is then restricted only to the firms of the same adjustment cell, i.e. the quintile of propensity scores.

In a third step the 'structurally similar' firm inside an adjustment cell was identified for each treated firm. In order to test the robustness of our results, we used four different matching methods to identify the structurally similar firms out of the pool of the non-treated firms. According to the first method used in this study, *nearest neighbour* matching, the 'twin' firm j to firm i is one fulfilling the condition:

$$min_{ij} /P_i - P_j/ \quad (2)$$

where P_i, and P_j are propensity scores for the firms i and j, respectively. The treated firm can have a higher or a lower propensity score than the non-treated one, therefore the absolute value of the difference of the two propensity scores has to be considered.

The second method used in this study, *calliper* matching, is based on the same proximity measure as the nearest neighbour method which in this case is restricted up to a certain value ε (maximum admissible difference of the propensity scores):

$$/P_i - P_j/ < \varepsilon (3)$$

Different adjustment cells can have different ε values. The ε values are dependent on the distribution of the propensity scores inside an adjustment cell.

According to the third method, *kernel* matching, a weighted sum of all available control group firms inside an adjustment cell, not a single 'twin' firm as in the other two methods, is ascribed to every treated firm. The performance difference between the treated and the non-treated firms is now defined as:

$$\Delta Y = Y_{1i} - \sum_{j \in \{d=0\}} w_{ij} Y_{0j} \quad (4)$$

where

w_{ij} is the weighting factor

($\sum_{j \in \{d=0\}} w_{ij} = 1; 0 \le w_{ij} \le 1, \forall d$)

The weighting factor in equation (4) is defined as:

$$w_{ij} = \frac{G_{ij}}{\sum_{k \in \{d=0\}} G_{ik}} \quad (5)$$

where

$\left(\frac{(P_i - P_k)}{a_{N_0}} \right)$ is the kernel[6] at the point $G_{ik} = G\left(\frac{(P_i - P_k)}{a_{N_0}} \right)$

a_{N_0} is the bandwidth of the kernel

The bandwidth was set specifically for every adjustment cell. Also in this case the choice of the bandwidth was dependent on the distribution of the propensity scores in the adjustment cells.

The fourth and last method, the *local linear regression* matching, is based on the same concept as kernel matching. In this case all available observations of the control group are also given a specific weight. This weight is high for small 'distances' between a pair of firms, low for large 'distances' and also contains a linear term. The weighting factor is defined as follows:

$$W_{N_0N_1}(i,j)=\frac{A-B}{C-D} \quad (6)$$

where

$$A=G_{ij}\sum_{k\in\{d=0\}}G_{ik}\left(P_k-P_i\right)^2$$

$$B=G_{ij}\left(P_j-P_i\right)\left[\sum_{k\in\{d=0\}}G_{ik}\left(P_k-P_i\right)\right]$$

and

$$C=\sum_{j\in\{d=0\}}G_{ij}\sum_{k\in\{d=0\}}G_{ik}\left(P_k-P_i\right)^2$$

$$D=\sum_{k\in\{d=0\}}G_{ik}\left(P_k-P_i\right)^2$$

$G_{ik}=G\left(\frac{P_k-P_i}{a_N}\right)$ is the kernel[7] at the point $\left(\frac{(P_i-P_k)}{a_{N_0}}\right)$

In a fifth step, the means of the variables measuring innovation performance of the group of the treated firms and the group of the 'twin' non-treated firms were compared. We used six innovation variables covering the output side of the innovation process:

- an ordinal measure of the *technical* importance of the introduced product and process innovations;[8]
- an ordinal measure of the *economic* importance of the introduced product and process innovations;[9]
- percentage reduction of average variable production costs due to process innovation;
- sales of new products new to the firm or to the market as a percentage of total sales;
- sales of significantly improved or modified (already existing) products as a percentage of total sales; and
- sales of products new to the market worldwide.

We use several innovation indicators in order to test the robustness of our results given that innovation is a latent phenomenon and every single indicator measures only partly aspects of this complex phenomenon.

In a sixth and last step we calculated a *subsidy quotient* for every subsidized firm by dividing the amount of the granted subsidy by the total R&D expenditures in the period 2000–2002. This subsidy quotient measured the relative magnitude of the subsidy.[10] We divided the subsidized firms into two groups: one group with firms with a subsidy quotient higher than the median ('high-subsidy' firms) and a second one with firms with a subsidy quotient lower than the median ('low-subsidy' firms). Then, we calculated the difference of the means between subsidized and non-subsidized firms separately for the 'high-subsidy' and the 'low-subsidy' firms. We tested if the difference in the former case was significantly larger than the difference in the latter case. If this was the case, we interpreted this result as empirical evidence that the impact of the CTI subsidies was positively correlated to the magnitude of the subsidy quotient. Hence, 'high-subsidy' firms would show a larger impact than the 'low-subsidy' ones.

Results of the matched-pairs analysis

Comparison of the innovation performance of subsidized firms depending on the subsidy quotient

Table 4 provides a qualitative summary of the results of the comparison of the innovation performance, as measured by six different indicators, of the subsidized and the non-subsidized firms for four different matching methods. We calculated the difference of the means of the two categories of firms (subsidized, non-subsidized) for six innovation variables and four matching methods, i.e. for 24 different cases. With one exception ('importance of introduced innovations from an *economic* point of view'; 'nearest neighbour' method) we found that the subsidized firms showed a *significantly higher*

Table 4. Summary of results with respect to *receiving a subsidy* for various matching methods

Variable	Significantly *higher* means of subsidized than of non-subsidized firms (after matching)			
	Nearest neighbour	Calliper	Kernel	Local linear regression
Importance of introduced innovations from a *technical* point of view*	Yes	Yes	Yes	Yes
Importance of introduced innovations from an *economic* point of view*	No	Yes	Yes	Yes
Percentage reduction of average variable production costs due to process innovation	Yes	Yes	Yes	Yes
Sales of significantly improved or modified (already existing) products as a percentage of total sales	Yes	Yes	Yes	Yes
Sales of products new to firm or to market as a percentage of total sales	Yes	Yes	Yes	Yes
Sales of products new to market worldwide as a percentage of total sales	Yes	Yes	Yes	Yes

Notes: *Originally ordinal variable measured separately for product and process innovations on a five-point Likert scale (1 = very small, 5 = very high). Mean values are used for product and process innovations. Statistical significance: 5% test level

It is interesting to note, particularly for policy-makers, that subsidized firms seem to be significantly more innovative, especially in terms of new products, than non-subsidized ones

innovation performance than non-subsidized firms (at the 5% test level). Hence, these results seem to be quite robust across various methods and innovation indicators. Having controlled for the size and age of the firms, sector affiliation, region, export propensity, and the existence of continuous R&D activities in the propensities equation, these performance differences have to be traced with good reason to the main difference between the two groups of firms, namely having or not having received subsidies from the CTI in the reference period. For the effectiveness of CTI promotion policy is the result for the six output-oriented innovation indicators of particular interest. Subsidized firms show a significantly higher innovation performance than structurally similar non-subsidized enterprises.

The detailed results in terms of figures for each innovation measure and each method are found in Tables A3–A6 in the Appendix. For example, column 1 in Table A3 shows the mean value (score) for every innovation indicator for all available non-subsidized firms before matching. Column 2 presents the mean values for the matched non-subsidized firms, i.e. those firms that were selected (out of the pool of non-subsidized firms) by the matching method used (in this case: 'nearest neighbour' method) as 'similar' to the subsidized ones. The figures in the latter case are systematically larger than in the former case, reflecting the fact that firms with a high innovation performance are selected by the applied method to match subsidized firms that are expected to be highly innovative in order to obtain grants. Column 3 shows the corresponding figures for the subsidized firms. Column 4 shows the difference between the mean values for the subsidized firms (column 3) and the mean values of the matched non-subsidized firms (column 2). Finally, column 5 presents the results of tests of the statistical significance of the differences in column 4.

These results show that there are substantial differences in innovation performance. For the output-oriented indicators the differences vary significantly between only 9–11% for the qualitative self-assessment of the technical importance of the innovations introduced and a threefold to fivefold larger magnitude in the case of sales of products new to the market. A further interesting point, particularly for policy-makers, is that subsidized firms seem to be significantly more innovative especially in terms of new products than non-subsidized ones.

Comparison of the innovation performance of 'high subsidy' and 'low subsidy' firms

Table 5 contains a qualitative summary of the results of the comparison of the differences of the innovation performance of 'high-subsidy' and

Table 5. Summary of results with respect to the magnitude of the subsidy quotient for various matching methods

Variable	**Significantly *higher differences of differences of* means of subsidized and non-subsidized firms (after matching) for subsidized firms with a subsidy quote > median than for subsidized firms with subsidy quotient < median**			
	'Nearest neighbour'	**'Calliper'**	**'Kernel'**	**'Local linear regression'**
Importance of introduced innovations from a *technical* point of view *	Yes	Yes	Yes	Yes
Importance of introduced innovations from an *economic* point of view *	No	No	No	No
Percentage reduction of average variable production costs due to process innovation	Yes	Yes	Yes	Yes
Sales of significantly improved or modified (already existing) products as a percentage of total sales	Yes	Yes	Yes	Yes
Sales of products new to the firm or to the market as a percentage of total sales	Yes	Yes	Yes	Yes
Sales of products new to the market worldwide as a percentage of total sales	Yes	Yes	Yes	Yes

Notes: *Originally ordinal variable measured separately for product and process innovations on a five-point Likert scale (1 = very small, 5 = very high). Mean values are used for product and process innovations. Statistical significance: 5% test level 'low-subsidy' firms from that of the respective groups of non-subsidized firms. For five innovation indicators we found that the difference of the means of the 'high-subsidy' and the non-subsidized firms is significantly higher (at the 10% level) for all four matching methods than the respective differences for the 'low-subsidy' firms (i.e. significantly *positive* difference of the differences). Hence, for these cases we have some empirical evidence that the impact on innovation performance is dependent on the relative magnitude of the subsidy granted. The larger the amount of the subsidy relative to a firm's own R&D investment, the stronger is the impulse for the innovation performance of a firm. For one innovation variable ('importance of introduced innovations from an *economic* point of view') we could not find any significant effect, meaning that relatively larger subsidies do not necessarily result in a stronger tendency by subsidized as compared to non-subsidized firms to introduce innovations that are economically important. It appears that larger subsidies result in more technologically important innovations in subsidized firms than in non-subsidized firms. This is understandable given that all subsidized collaborations are between firms and universities that provide co-operating firms with knowledge that is primarily of high technological value. This does not mean that higher subsidies cannot generate (additional) economic success: according to our results the larger the subsidy (in relative terms), the larger the impact effect for a series of indicators that measure the economic success of innovation (sales shares of products with different grades of innovativeness, reduction in costs).

More detailed results in terms for figures for each innovation measure and each method can be found in Tables A7–A10 in the Appendix. For example, column 1 in Table A7 shows the differences between subsidized firms with subsidy quotients *smaller* than the median and the corresponding matched non-subsidized firms. Column 2 presents the results with respect to the statistical significance of these differences. Columns 3 and 4 show the differences between subsidized firms with subsidy quotients *larger* than the median, column 4 refers to the statistical significance of these differences. Finally, column 5 reports on the results of tests of the statistical significance of the difference of the differences of the means. As we can see, the difference between subsidized and non-subsidized firms, for example, for the sales shares of products that are new worldwide for firms with small subsidy quotient *increases* from 7.10 percentage points to 12.60 percentage points for firms with large subsidy quotients. The respective increase for the sales shares of new products (either new to the firm or new to the market) amounting to 18.20 − 8.00 = 10.20 percentage points as well as for significantly improved products (amounting to 14.90 − 7.60 = 7.30 percentage points) are even larger.

Conclusion

Based on a matched-pairs analysis of 199 firms supported by the CTI in the period 2000–2002 and a control group of 996 firms that were not supported by the CTI, we found that the CTI promotion significantly improved the innovation performance of supported firms with respect to six different measures of innovation performance. This could be shown by four different matching methods (with the exception of the nearest neighbour method for the indicator 'importance of introduced innovations from an *economic* point of view').

A further finding was that the magnitude of the impact correlated positively with the relative size of financial support as measured by the quotient of the volume of financial support to the volume of a supported firm's own R&D expenditures. The present analysis yields some information on three policy-related issues:

- the type of enterprises that received subsidies from the CTI;
- the effectiveness of CTI promotion policy; and
- the relationship between subsidy quotient and policy effectiveness.

The results of the study show a positive picture of the CTI's promotion policy. Subsidized firms are mainly small- and medium-sized enterprises (perhaps too many micro-firms among them) whose promotion is an explicit goal of CTI policy, the technological orientation of subsidized projects is quite broad, also covering currently fashionable fields such as biotechnology and nanotechnology. Further, subsidized firms represent a wide spectrum of manufacturing firms, the concentration on firms for machinery, electronics and instruments reflecting the current structure of Swiss manufacturing. The 'bottom-up' principle applied by the CTI for allocating funds seems to be quite effective. An additional positive element is that policy is not just effective but it becomes more effective if the financial support is raised. All this is also in accordance with the general principles of the Swiss technology policy tending to be 'non-activist', providing primarily for the improvement of framework conditions for private innovation activities.

Even if a policy measure is successful from a microeconomic point of view, it still remains an open question whether or not this policy measure is also relevant in macroeconomic terms. In the case of the CTI policy investigated in this paper, it is questionable if an amount of about CHF60 million in 2004 (meanwhile CHF100–150 million of additional R&D support per annum) could have a discernible impact on an economy that invested about CHF19 billion in R&D in 2004. A further open question is, of course, if some kind of 'functional equivalent' of this policy at a broader base, e.g. R&D tax incentives would do better, but such a discussion would be beyond the scope of this empirical paper.

Appendix

Table A1. Survey of subsidized enterprises: structure of answering enterprises by scientific field

Scientific field	Number of addressed enterprises	Number of answering enterprises	Percentage share of answering enterprises
Construction technology	16	11	68.8
Biology	13	7	53.8
Electrical machinery/electronics	18	12	66.7
Information technology	38	20	52.6
Machinery	70	46	65.7
Material sciences	33	20	60.6
Microelectronics	27	16	59.3
Nanotechnology	6	5	83.3
Process engineering	29	15	51.7
Production/management concepts	23	14	60.9
Other	34	19	55.9
Total	**307**	**185**	**60.3**

Table A2. Propensity of having a research project subsidized by CTI as function of various firm characteristics (probit estimation; dependent variable: research project subsidized by CTI in period 2000–2002, yes/no)

Firm characteristics	Test level 5%	Firm characteristics	Test level 5%
Firm size:		**Sector:**	
20–49 employees	-0.31	Traditional manufacturing	-0.54
	(0.11)		(0.10)
50–99 employees	-0.52	Traditional service industries	-1.23
	(0.13)		(0.23)
100–199 employees	-0.45	Modern service industries	
	(0.12)	*Region:*	
200–499 employees		Region of Lake Geneva	
500–999 employees		Midlands region	
1000 employees and over		North western Switzerland	-0.30
Other characteristics:			(0.14)
Continuous R&D activities	0.40	Eastern Switzerland	
	(0.10)	Central Switzerland	
Export activities	0.43	Ticino	
	(0.11)	**Language of questionnaire:**	
Firm founded before 1996	-0.86	French	0.56
	(0.14)		(0.10)
		German	
		N	1317
		Adj. McFadden-R^2	0.14
		% concordance	76.50

Notes: Only coefficients of variables that were significant at the 5% level are reported
All variables in table are dummy variables
Reference group for firm size: up to 19 employees
Reference sector: high-tech manufacturing; definition: high-tech manufacturing: chemistry, plastics, machinery, electrical machinery, electronics/instruments; modern service industries: banking/insurance, computer services; other business services; traditional manufacturing: food/beverage/tobacco, textiles, clothing/leather; wood processing, paper, printing, glass/stone/clay, metal, metalworking, watches, other manufacturing, energy; traditional service industries: wholesale trade, retail trade, transport/telecommunication, hotels/catering, personal services
Reference region: Zurich
Reference language: Italian

(continued)

Appendix (*continued*)

Table A3. Comparison of subsidized/non-subsidized enterprises, matched by 'nearest neighbour' method

Measures of innovation performance	**All non-active firms before matching**	**Non-active firms after matching (control group)**	**Active firms**	**Difference in means of active firms/non-active firms (column 3 – column 2)**	
		Means			**Statistical significance (test level 5%)**
Importance of introduced innovations from a *technical* point of view*	3.34 (0.03)	3.44 (0.05)	3.75 (0.06)	0.31 (0.08)	Yes
Importance of introduced innovations from an *economic* point of view*	3.36 (0.03)	3.60 (0.06)	3.65 (0.06)	0.005 (0.081)	No
Percentage reduction of average variable production costs due to process innovation	4.98 (0.29)	3.59 (0.43)	8.61 (1.24)	5.02 (1.32)	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	33.73 (0.84)	36.60 (1.61)	48.36 (2.39)	11.76 (3.01)	Yes
Sales of products new to firm or to market as percentage of total sales	15.73 (0.57)	17.24 (1.39)	27.46 (2.27)	10.22 (2.73)	Yes
Sales of products new to market worldwide as a percentage of total sales	4.44 (0.39)	3.01 (0.36)	15.58 (2.10)	12.57 (2.10)	Yes

Notes: * Originally ordinal variable measured separately for product and process innovations on a five-point Likert scale (1 = very small, 5 = very high)
Mean values are used for product and process innovations
Number of non-subsidized firms = 996; number of subsidized firms = 199
Standard errors are in brackets under the means
Two-tailed t-test used for difference of means

Table A4. Comparison of subsidized/non-subsidized enterprises, matched by 'calliper' method

Measures of innovation performance	**All non-active firms before matching**	**Non-active firms after matching (control group**	**Active firms**	**Difference of means of active firms/non-active firms (column 3 – column 2)**	
		Means			**Statistical significance (test level 5%)**
Importance of introduced innovations from a technical point of view*	3.34 (0.03)	3.36 (0.02)	3.75 (0.06)	0.39 (0.06)	Yes
Importance of introduced innovations from an economic point of view*	3.36 (0.03)	3.43 (0.01)	3.65 (0.06)	0.22 (0.06)	Yes
Percentage reduction of average variable production costs due to process innovation	33.73 (0.84)	36.32 (0.43)	48.36 (2.39)	12.04 (2.47)	Yes
Sales of significantly improved or modified (already existing) products as a percentage of total sales	4.98 (0.29)	5.71 (0.12)	8.61 (1.24)	2.90 (1.24)	Yes
Sales of products new to firm or to market as a percentage of total sales	15.73 (0.57)	17.28 (0.27)	27.46 (2.27)	10.18 (2.34)	Yes
Sales of products new to market worldwide as a percentage of total sales	4.44 (0.39)	5.94 (0.18)	15.58 (2.10)	9.64 (2.01)	Yes

Notes: * See footnotes to Table A3 for key

(*continued*)

Appendix (*continued*)

Table A5. Comparison of subsidized/non-subsidized enterprises, matched by 'kernel' method

Measures of innovation performance	All non-active firms before matching	Non-active firms after matching (control group)	Active firms	Difference of means of active firms/non-active firms (column 3 – column 2)	
	Means				Statistical significance (test level 5%)
Importance of introduced innovations from a *technical* point of view*	3.34 (0.03)	3.39 (0.02)	3.75 (0.06)	0.36 (0.06)	Yes
Importance of introduced innovations from an *economic* point of view*	3.36 (0.03)	3.46 (0.01)	3.65 (0.06)	0.19 (0.06)	Yes
Percentage reduction of average variable production costs due to process innovation	4.98 (0.29)	5.85 (0.11)	8.61 (1.24)	2.76 (1.22)	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	33.73 (0.84)	36.01 (0.39)	48.36 (2.39)	12.35 (2.44)	Yes
Sales of products new to firm or to market as ercentage of total sales	15.73 (0.57)	16.94 (0.30)	27.46 (2.27)	10.52 (2.36)	Yes
Sales of products new to market worldwide as percentage of total sales	4.44 (0.39)	5.82 (0.17)	15.58 (2.10)	9.76 (2.10)	Yes

Notes:* See footnotes to Table A3 for key

Table A6. Comparison of subsidized/non-subsidized enterprises, matched by 'local linear regression' method

Measures of innovation performance	All non-active firms before matching	Non-active firms after matching (control group)	Active firms	Difference of means of active firms/non-active firms (column 3 – column 2)	
	Means				Statistical significance (test level 5%)
Importance of introduced innovations from a *technical* point of view*	3.34 (0.03)	3.39 (0.02)	3.75 (0.06)	0.36 (0.06)	Yes
Importance of introduced innovations from an *economic* point of view*	3.36 (0.03)	3.46 (0.01)	3.65 (0.06)	0.19 (0.06)	Yes
Percentage reduction of average variable production costs due to process innovation	4.98 (0.29)	5.85 (0.11)	8.61 (1.24)	2.76 (1.22)	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	33.73 (0.84)	36.01 (0.39)	48.36 (2.39)	12.35 (2.44)	Yes
Sales of products new to firm or to market as percentage of total sales	15.73 (0.57)	16.94 (0.30)	27.46 (2.27)	10.52 (2.36)	Yes
Sales of products new to market worldwide as a percentage of total sales	4.44 (0.39)	5.82 (0.17)	15.58 (2.10)	9.76 (2.10)	Yes

Notes:* See footnotes to Table A3 for key

(*continued*)

Appendix (*continued*)

Table A7. Results with respect to magnitude of subsidy quotient for 2000–2002, calculated using 'nearest neighbour' method

Measures of innovation performance	Subsidized firms: subsidy quotient > median		Subsidized firms: subsidy quotient < median		
	Difference of means of subsidized / non-subsidized firms	Statist. signif. (test level 10%)	Difference of means of subsidized / non-subsidized firms	Statist. signif. (test level 10%)	Difference of the difference of the means (column 3 − column 2)
Importance of introduced innovations from a *technical* point of view*	0.42	Yes	0.18	Yes	Yes
Importance of introduced innovations from an *economic* point of view*	0.05	No	0.03	No	No
Percentage reduction of average variable production costs due to process innovation	6.80	Yes	3.80	Yes	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	13.90	Yes	8.20	Yes	Yes
Sales of products new to firm or to market as percentage of total sales	17.90	Yes	7.10	Yes	Yes
Sales of products new to market worldwide as percentage of total sales	15.50	Yes	9.80	Yes	Yes

Notes:* See footnotes to Table A3 for key

Table A8. Results with respect to magnitude of subsidy quotient (2000–2002) using 'calliper' method

Measures of innovation performance	Subsidized firms: subsidy quotient > median		Subsidized firms: subsidy quotient < median		
	Difference of means of subsidized / non-subsidized firms	Statist. signif. (test level 10%)	Difference of means of subsidized/non-subsidized firms	Statist. signif. (test level 10%)	Difference of difference of means (column 3 − column 2)
Importance of introduced innovations from a *technical* point of view*	0.46	Yes	0.33	Yes	Yes
Importance of introduced innovations from an *economic* point of view*	0.13	No	0.26	Yes	No
Percentage reduction of average variable production costs due to process innovation	4.10	Yes	1.90	Yes	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	14.10	Yes	7.20	Yes	Yes
Sales of products new to firm or to market as percentage of total sales	17.90	Yes	7.70	Yes	Yes
Sales of products new to market worldwide as percentage of total sales	12.60	Yes	7.20	Yes	Yes

Notes:* See footnotes to Table A3 for key

(*continued*)

Appendix (*continued*)

Table A.9. Results with respect to magnitude of subsidy quotient (2000–2002) using 'kernel' method

Measures of innovation performance	**Subsidized firms: subsidy quotient > median**		**Subsidized firms: subsidy quotient < median**		
	Difference of means of subsidized / non-subsidized firms	**Statist. signif. (test level 10%)**	**Difference of means of subsidized/ non-subsidized firms**	**Statist. signif. (test level 10%)**	**Difference of the difference of means (column 3 − column 2)**
Importance of introduced innovations from a *technical* point of view *	0.39	Yes	0.30	Yes	Yes
Importance of introduced innovations from an *economic* point of view *	0.08	No	0.24	No	No
Percentage reduction of average variable production costs due to process innovation	3.60	Yes	1.70	Yes	Yes
Sales of significantly improved or modified (already existing) products as percentage of total sales	14.40	Yes	7.60	Yes	Yes
Sales of products new to firm or to market as percentage of total sales	18.10	Yes	8.10	Yes	Yes
Sales of products new to market worldwide as percentage of total sales	13.10	Yes	7.20	Yes	Yes

Notes:* See footnotes to Table A3 for key

Table A.10. Results with respect to magnitude of subsidy quotient (2000–2002) using 'local linear regression' method

Measures of innovation performance	**Subsidized firms: subsidy quotient > median**		**Subsidized firms: subsidy quotient < median**		
	Difference of means of subsidized/non-subsidized firms	**Statist. signif. (test level 10%)**	**Difference of means of subsidized/non-subsidized firms**	**Statist. signif. (test level 10%)**	**Difference of difference of means (column 3 − column 2)**
Importance of introduced innovations from a *technical* point of view *	0.40	Yes	0.31	Yes	Yes
Importance of introduced innovations from an *economic* point of view *	0.09	No	0.24	No	No
Percentage reduction of average variable production costs due to process innovation	3.80	Yes	1.90	Yes	Yes
Sales of significantly improved or modified (already existing) products as a percentage of total sales	14.90	Yes	7.60	Yes	Yes
Sales of products new to firm or to market as a percentage of total sales	18.20	Yes	8.00	Yes	Yes
Sales of products new to market worldwide as a percentage of total sales	12.60	Yes	7.10	Yes	Yes

Notes:* See footnotes to Table A3 for key

Notes

1. See Bozeman (2000); Georghiou and Roessner (2000); and Feller (2007) for recent reviews of the central issues related to the evaluation of the effectiveness of technology programmes. See also *Science and Public Policy* (**34**(10), 679–752) dedicated to 'New frontiers in evaluation'. Finally, see OECD (2006a) for an analysis more from the point of view of the policy-maker; Polt *et al*. (2001) for the role of framework conditions for the evaluation of industry–university collaborations; and Polt and Streicher (2005) for the evaluation of large programmes such as the Framework Programmes of the European Union.
2. For overviews of Swiss technology policy see OECD (2006b) and European Commission (2008). Lepori (2006) gives a long-term analysis of public research policy primarily with respect to universities and public research organizations. Griessen and Braun (2006) deal with the problems of political coordination of innovation policies in Switzerland.

3. The questionnaire may be obtained from the authors. It is available in German, French and Italian.
4. The expression ‘treatment effect’ comes from labour market research, where individuals are ‘treated’ via a concrete policy measure. It is used here analogously for firms subsidized by the CTI.
5. See Heckman *et al*. (1999) for a survey on various matching procedures. Caliendo and Huber (2005) and Caliendo and Kopeinig (2005) give overviews of recent developments with respect to matching methods.
6. We used a ‘biweight kernel’ (quartic kernel) for the function G(.). It is defined as follows:

$$15/16\left(1-(P_i-P_k)/a_{N_0})^2\right)^2$$

The results are sensitive, not to the kernel function used, but to the choice of the bandwidth.

7. We also used the ‘biweight kernel’ here (see Note 6). The bandwidth was determined as follows (Silverman, 1986):

$$a_N = 2.7768(H / 1.34)N^{-1/5}$$

where N is the number of observations of the control group or the group of treated firms, and H is the distance between the quintiles. For the adjustment cell 5 we used a bandwidth of 0.15.

8. The ordinal variable was originally measured separately for product and process innovations on a five-point Likert scale (1 = very small, 5 = very high); here we use the mean values for the product and process innovations.
9. See Note 8.
10. There is some measurement error in this calculation due to the time incongruence between subsidies granted before the beginning of 2000 and R&D expenditures strictly referring to the period 2000–2002 that unfortunately cannot be quantified and corrected. In order to minimize the influence of this error we distinguish only two ‘crude’ groups of subsidized firms.

References

Almus, M, and D 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**(2), 226–236.

Arvanitis, S and M Keilbach 2002. Evaluation methodologies, econometric models: microeconometric models. In *RTD Evaluation Tool Box: Socio-Economic Evaluation of Public RTD Policies (EPUB)*, W Polt, J. Rojo, A Tübke, G Fahrenkrog and K Zinöcker (eds.), pp 101–118. Vienna: European Commission.

Arvanitis, S, H Hollenstein and S Lenz 2002. The effectiveness of government promotion of advanced manufacturing technologies (AMT): an economic analysis based on Swiss micro data. *Small Business Economics*, **19**(4), 321–340.

Arvanitis, S, H Hollenstein, N Sydow and M Wörter 2007. *Innovationsaktivitäten in der Schweizer Wirtschaf t– Eine Analyse der Ergebnisse der Innovationserhebung 2005*. Bern: Staatssekretariat für Wirtschaft.

Arvanitis, S, J Von Arx, H Hollenstein and N Sydow 2004. Innovationsaktivitäten in der Schweizer Wirtschaft - Eine Analyse der Ergebnisse der Innovationserhebung 2002. Bern: Staatssekretariat für Wirtschaft.

Arrow, K J 1962. Economic welfare and the allocation of resources to invention. In *The Rate and Direction of Inventive Activity*, R Nelson (ed.). Princeton, NJ: Princeton University Press.

Bérubé, C and P Mohnen 2007. Are firms that received R&D subsidies more innovative? UNU-MERIT Working Paper No. 2007-015. Maastricht: UNU-MERIT.

Bozeman, B 2000. Technology transfer and public policy: a review of research and theory. *Research Policy*, **29**(4/5), 627–655.

Busom, I 2000. An evaluation of the effects of R&D subsidies. *Economics of Innovation and New Technology*, **9**(2), 111–148.

Caliendo, M and R Huber 2005. The microeconometric estimation of treatment effects: an overview. IZA Discussion Paper No. 1653. Bonn, Germany: IZA (Institute for the Study of Labour).

Caliendo M. and S Kopeinig 2005. Some practical guidance for the implementation of propensity score matching. *DIW Discussion Paper No*. 485. Berlin: DIW (German Institute for Economic Research).

Czarnitzki, D and A Fier 2002. Do innovation subsidies crowd out private investment? Evidence from the German service sector, ZEW Discussion Paper No. 02-04, Mannheim, Germany: ZEW.

David, P, B Hall and A Toole 2000. Is public R&D a complement for private R&D? *Research Policy*, **29**(4/5), 497–529.

Donzé, L 2002. Matched-pair analysis based on business survey data to evaluate the policy of supporting the adoption of advanced manufacturing technologies by Swiss firms, KOF Working Paper No. 65, July 2002. Zurich: KOF.

European Commission 2008. Annual innovation policy trends and appraisal report: Switzerland 2007–2008 – European trend chart on innovation. Brussels: European Commission.

Feller, I 2007. Mapping the frontiers of evaluation of public-sector R&D programmes. *Science and Public Policy*, **34**(10), 681–690.

Garcia-Quevado, G 2004. Do public subsidies complement business R&D? A meta-analysis of the econometric evidence. *Kyklos*, **57**(1), 87–102.

Georghiou, L and D Roessner 2000. Evaluating technology programmes: tools and methods. *Research Policy*, **29**(4/5), 657–678.

Görg, H and E Strobl 2007. The effect of R&D subsidies on private R&D. *Economica*, **74**(2), 215–234.

Griessen, T and D Braun 2008. The political coordination of knowledge and innovation policies in Switzerland. *Science and Public Policy*, **35**(4), 277–288.

Hall, B and J Van Reenen 2000. How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy*, **29**(4/5), 449–469.

Heckman, J, H Ichimura, J Smith, J. and P Todd 1998. Characterizing selection bias using experimental data. *Econometrica*, **66**(5), 1017–1098.

Heckman, J J, R J Lalonde, and J A Smith 1999. The economics and econometrics of active labour market programmes. In *Handbook of Labour Economics*, A Ashenfelter and P E Todd (eds.), pp 1865–2097. Amsterdam: Elsevier.

Jaffe, A B 2002. Building programme evaluation into the design of public research-support programmes. *Oxford Review of Economic Policy*, **18**(1), 22–34.

Jaumotte, F and N Pain 2005. An overview of public policies to support innovation, OECD Economics Department Working Papers No. 456. Paris: OECD.

Klette, T J, J Moen, and Z Griliches 2000. Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. *Research Policy*, **29**(4/5), 471–495.

Lach, S 2002. Do R&D subsidies stimulate or displace private R&D? *Journal of International Business Studies*, **50**(4), 369–390.

Lepori B 2006. Public research funding and research policy: a long-term analysis for the Swiss case. *Science and Public Policy*, **33**(3), 205–216.

Nelson, R R 1959. The simple economics of basic scientific research. *Journal of Political Economy*, **6**7(3), 297–306.

OECD 2006a. *Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality*. OECD: Paris.

OECD 2006b. *OECD Reviews of Innovation Policy: Switzerland*. Paris: OECD.

OECD 2007. *Science, Technology and Industry Board – Innovation and Performance in the Global Economy*. Paris: OECD.

Pointner, W and C Rammer 2005. Wirkungsanalyse. In *Diffusionsorientierte Technologiepolitik – Eine vergleichende Wirkungsanalyse für Österreich, die Schweiz, Deutschland und die USA*, W Pointner and W Polt (eds.). Vienna: Leykam.

Polt, W, C Rammer, H Gassler, A Scibany and D Schartinger 2001. Benchmarking industry–science relations: the role of framework conditions. *Science and Public Policy*, **28**(4), 247–258.

Polt, W and G Streicher 2005. Trying to capture additionality in Framework Programme 5: main findings. *Science and Public Policy*, **32**(5), 367–373.

Rosenbaum, B R and D B Rubin 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, **70**(1), 41–55.

Sakakibara, M 1997. Evaluation of government-sponsored R&D consortia in Japan. In *Policy Evaluation in Innovation and Technology – Towards Best Practices*, pp 225–253. OECD: Paris.

Silverman, R 1986. *Density Estimation*. London: Chapman and Hall.

Wallsten, S C 2000. The effects of government–industry R&D programmes on private R&D: The case of the Small Business Innovation Research Programme. *Rand Journal of Economics*, **31**(1), 82–100.