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The effects of R&D tax credits on patenting and innovations

Abstract:
Norwegian business spending on R&D is low by OECD standards. To stimulate business R&D, in 2002 the Norwegian government introduced a tax-based incentive, SkatteFUNN. We analyze the effects of SkatteFUNN on the likelihood of innovating and patenting. Using a rich database for Norwegian firms, we find that projects receiving tax credits result in the development of new production processes and to some extent the development of new products for the firm. Firms that collaborate with other firms are more likely to be successful in their innovation activities. However, the scheme does not appear to contribute to innovations in the form of new products for the market or patenting.

Keywords: Tax credits; R&D; Patenting; Innovation; Self-selection

JEL classification: C33; C52; D24; O38

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1. Introduction

Both economic theory and empirical evidence support the view that R&D plays a vital role in raising productivity on a sustainable basis (see, e.g., Griliches, 1992, and Romer, 1990). The social return on R&D investment is often higher than the private return to the investing firm. Thus, one can justify policy intervention if a well-designed intervention scheme can be implemented. Since the 1990s, OECD countries have tended to rely on fiscal policy incentives to promote R&D spending in the business sector. In 1996, 12 OECD countries offered tax incentives for R&D expenses; by 2004 this number had increased to 18, with Norway as one of the newcomers.

R&D incentives are designed in many different ways. Some countries offer incremental schemes targeting only increases in R&D expenses, while others have volume-based incentives. A few countries have both. Although more countries have introduced tax incentives over time, no consensus exists as to what is best practice. Evaluation of the incentives in various countries may help determine which policies or policy mixes work well.

R&D spending in the Norwegian business sector as a share of GDP is below the OECD average. To stimulate private R&D investment, the Norwegian government has traditionally used direct R&D subsidies. In 2002 Norway supplemented this policy with an R&D tax credit scheme—SkatteFUNN—for small and medium-sized enterprises (SMEs), which by 2003 became available to all firms. SkatteFUNN provides a volume-based tax credit to firms with an R&D project that the Norwegian Research Council has approved.[1] A tax credit of 18 percent (20 percent for SMEs) of R&D costs for the approved project is deductible from the firm's income tax, with a project cost cap roughly equal to half a million euros. If the firm does not pay any tax or pays less tax than the tax credit, the credit is paid to the firm as if it were a grant. Appendix A presents the SkatteFUNN scheme and its background in more detail.

In this paper we study the effects of SkatteFUNN on firms' innovation activities and patenting. We analyze three types of innovations: a new (or improved) product for the firm, a

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[1] The Norwegian Research Council does not evaluate either the "success probability" or the social return to the project. It is sufficient for approval to fulfill the formal criteria for being an R&D project, resulting in the acceptance of as many as 70–75 percent of applications each year.

new (or improved) product for the market, and a new (or improved) production process. We also have information on patent applications. We focus on the following three questions.

First, how is the introduction of innovations related to R&D? While R&D is obviously an important factor behind innovation, it is not the only one. The availability of high–skilled workers is another important factor. Moreover, the effects of R&D can vary depending on the firm's size, location and industry.

Second, does SkatteFUNN lead to more innovations? Hægeland and Møen (2007) find that firms receiving support through SkatteFUNN are more likely to increase their R&D investments than other firms. The question remains whether there is a causal relation between SkatteFUNN and firms' innovations.

Third, do the answers differ for different types of innovations? One important reason for government intervention in the market for R&D is to create spillovers. However, if firms receiving subsidies mainly innovate in the form of new products for the firm, but not for the market (i.e., imitate other firms), it is not clear that the scheme will reach those R&D activities with the largest potential for spillovers.

For the analysis, we use Norwegian microdata covering firms included in the 2001 and 2004 innovation surveys. These surveys contain information on the inputs and outputs of firms' innovative activities, e.g., whether firms have introduced product or process innovations and whether they have applied for a patent over the three-year period before each survey. The 2001 survey covers the three years before the introduction of SkatteFUNN (1999–2001), while the 2004 survey covers the three years following the introduction of SkatteFUNN (2002–2004). By supplementing these data with information from different registers, we obtain two repeated cross sections of the innovation variables (with many firms included in both surveys) and six years of observations on R&D and other variables.

Our modeling framework is influenced by Griliches (1990), Crepon et al. (1998) and Parisi et al. (2006). The main idea in this literature is that by investing in R&D, the firm accumulates R&D capital, which plays an important role in the innovation activity. Using binary regression models, we model the probability of innovating and patenting as a function of the R&D capital stock at the *beginning* of each three year period, participation in SkatteFUNN, and different firm characteristics (size, industry, share of highly skilled workers, etc.). Even if

R&D *investments* are simultaneously determined with innovations, the timing of our R&D variable allows us to consider the R&D capital *stock* as predetermined. Moreover, access to panel data gives us an opportunity to estimate models that explicitly take into account the persistence of innovation activities within firms by conditioning on past innovation and patenting activities. To identify causal effects of SkatteFUNN, we model the probability of obtaining SkatteFUNN and the probability of innovations simultaneously.

Our results show that the SkatteFUNN scheme contributes to an increase in the rate of innovation by firms. SkatteFUNN projects contribute to the development of new production processes and, to some extent, to new products for the firm. The firms that collaborate with other firms in their R&D activity are more likely to innovate. However, the scheme does not appear to contribute to innovations in the form of new products for the market or more patenting.

The structure of our paper is as follows. Section 2 describes our study in the context of the existing literature. Section 3 presents the data and provides descriptive statistics on R&D, innovations and patent applications. Section 4 describes the model framework. Section 5 presents the results, and Section 6 concludes.

2. Our study in the context of the existing literature

There exists a relatively large literature evaluating the effects of public R&D subsidies on firms' R&D investment. Some recent examples include Wallsten (2000), who examined the U.S. Small Business Innovation Research program, Lach (2000), who studied an Israeli scheme of R&D subsidies for manufacturing firms, and Almus and Czarnitzki (2003), who studied a German R&D subsidy program. These studies focus on possible crowding-out effects; i.e., whether the firms substitute their private R&D investments with public R&D funding. Very few studies examine effects on output measures, such as patent applications and innovations. One such study is the evaluation of the Dutch R&D subsidy program (WBSO); cf. de Jong and Verhoeven (2007), who examined how WBSO influences the proportion of turnover from sales of new products and services. They reported a significant positive effect of WBSO on their output measure. However, like most other studies in this area, they did not pay attention to selection bias problems, contrary to the recommendations of Klette et al. (2000) and David et al. (2002). The latter two studies pointed out the necessity of controlling for self-selection bias when evaluating the effects of R&D programs.

When evaluating a public policy program, one must address the following counterfactual question: what is the change in the response variable, *Y*, compared with the value *Y* would have had in the absence of the program? One cannot answer this question just by regressing *Y* (e.g., the number of patent applications) on a dummy for whether the firm has participated in the scheme, *D*. The reason is that observed and unobserved variables that affect the dependent variable, *Y*, may also affect the outcome of *D*; i.e., we may have a case of self-selection into the program. In the example with SkatteFUNN, firms that already are engaged in R&D activities have a larger probability of applying for an R&D subsidy than other firms do; i.e., there is "selection based on observables". There may also be "selection based on unobservables". For example, the decision to apply for SkatteFUNN may be based on the (unobserved) probability of success for already ongoing projects. Ignoring selection problems may lead to seriously biased estimates of causal effects. Indeed, our study shows that the way we control for self-selection has a major impact on the results.

A popular approach to the self-selection problem is propensity score matching. The basic assumption behind this approach is that there exists a vector of exogenous covariates, X, such that *Y* and *D* are independent given X (i.e., conditional independence). According to a result in Rosenbaum and Rubin (1983), a *treated* firm (meaning that $D = 1$) and a *nontreated* firm ($D = 0$) can be matched if they have identical probability of participating in the program, given *X*. That is, they can be considered as if they were equal in all other respects (except for an additive error term). The difference in Y can then be calculated for all *matched pairs* and the average value of these differences is a valid estimator of the average treatment effect among the treated. This idea was applied by Almus and Czarnitzki (2003). However, we will argue that the "selection on observables" assumption behind this approach is not appropriate for the Norwegian SkatteFUNN scheme.

In the presence of "selection based on unobservables" other methods must be pursued. Busom (2000) applies a two-stage or control function approach based on Heckman (1976, 1979). In this approach, an equation for whether firms participate in a public funding program is estimated in the first stage, from which suitable variables ("control functions") are computed, and included as additional regressors in the second stage when estimating the effects of the program. Selection based on unobservables is also essential in the model of Crepon et al. (1998), often referred to as the CDM model. The CDM model assumes that there exists an unobserved variable for each firm that expresses some profitability criterion that governs the firm's decision to undertake R&D or not. If the unobserved variable exceeds some threshold, the firm will undertake a certain amount of R&D and we can observe its R&D intensity. Because R&D is an endogenous explanatory variable, it is replaced by its predicted value obtained from the first step of the (recursive) CDM model. In the second stage, various innovation variables (patenting, share of innovative sales out of total sales, etc.) are modeled conditional on the R&D activity of the firm. In addition, variables such as capital intensity, firm size, industry dummies, and demand pull and technology push factors are used as covariates.

Although Crepon et al. (1998) are not concerned with policy evaluation *per se*, they address selectivity issues that are highly relevant also in an evaluation context. As we discuss later, it is likely that access to various forms of external funding is endogenous to the firm and may impair the estimated effects of policy interventions. Our approach can be seen as combining the CDM model with the control-function methodology of Busom (2000), although there are some notable differences. First, access to panel data enables us to condition on lagged innovation and patenting variables, both in the equation determining participation in SkatteFUNN and in the equation for innovation or patenting. Second, we also allow the effects of SkatteFUNN to differ between firms by incorporating random coefficients. Finally, because we use nonlinear binary-regression models in the second stage, the standard control function approach cannot be applied directly as in Busom (2000). Instead we consider a pseudo maximum likelihood modification of this approach.

3. Data and descriptive statistics on R&D, innovations and patents

3.1 Data and variables construction

For the analysis, we use Norwegian microdata on the firms included in the 2001 and 2004 innovation surveys, covering the three-year periods 1999–2001 and 2002–2004, respectively. These data are collected by Statistics Norway as a part of the annual R&D survey (we refer to them as *R&D statistics*). They contain detailed information on firms' R&D and innovation activities, including total R&D expenditures (divided into intramural R&D and extramural R&D services), whether the firm has introduced a new product (for the firm or for the market) or a process innovation, and whether it has applied for a patent over the corresponding three year period (henceforth referred to as a *subperiod)*. The sample for the survey is selected using a stratified method for firms with 10–50 employees, whereas all firms with more than 50 employees are included. The strata are based on industry classification (NACE codes) and firm size. Each survey contains about 5000 firms. By supplementing these data with information from the Tax Register, the Register of Employers and Employees (REE) and the National Education Database (NED), we obtain two repeated cross sections of the innovation variables and six years of observations on R&D and other variables. Table 1 presents an overview of the main variables and the data sources applied in our study.

Table 1. Overview over variables and data sources

Variable	Definition	Data source(s)
inpdt	1 if firm has introduced a new product for the firm in the given subperiod, 0 else	R&D statistics
inmar	1 if firm has introduced a new product for the market in the given subperiod, 0 else	R&D statistics
inpcs	1 if firm has introduced a new production process in the given subperiod, 0 else	R&D statistics
d_patent	1 if firm has applied for a patent in the given subperiod, 0 else	R&D statistics
R	R&D investment in the given year	R&D statistics
d_R	1 if $R > 0$ in at least one year in the given subperiod, 0 else	R&D statistics
RK	R&D capital stock at the end of the given year	R&D statistics
rk	R&D capital intensity: *RK*/man-hour	R&D statistics/REE
coopf	1 if firm cooperated with another firm in R&D in the given subperiod, 0 else	R&D statistics
coopu	1 if firm cooperated with a university or research institute in R&D in the given subperiod, 0 else	R&D statistics
SFS	SkatteFUNN subsidy in the given year	Tax register
d_SFS	1 if $SFS > 0$ in at least one year in the given subperiod, 0 else	Tax register
ac	Share of man-hours worked by employees with academic education (17 or more years of education)	REE/NED

Note: Subperiod includes the last three years.

The first three variables in Table 1, *inpdt, inmar* and *inpcs*, are dummy variables indicating whether the firm has introduced a new product for the firm, a new product for the market or a new production process (during the corresponding subperiod), while the dummy variable *d_patent* indicates whether the firm has applied for a patent during the same period. All these variables are measures of how innovative the firm is and are considered as dependent variables in our analysis.

R&D investment, *R*, is annual R&D investment as it is reported in the questionnaire, deflated by the index for labor costs of R&D in the private sector (Norwegian Research Council, 2003).[2] The dummy variable *d_R* indicates whether the firm has invested in R&D in at least one year during the last three years.

The (real) R&D capital stock at the end of a given year *t*, RK_t is computed by the perpetual inventory method using a constant rate of depreciation ($\delta = 0.15$). That is:

$$RK_t = (1-\delta)RK_{t-1} + R_t,\ t = 1,2,\ldots.$$

Following Hall and Mairesse (1995), the benchmark for R&D capital stock at the beginning of the observation period for a given firm, RK_0, is calculated as if it was the result of an infinite R&D investment series, R^*_{-t}, $t = 0,1,2\ldots$, with a fixed presample growth rate ($g = 0.05$). That is:

$$RK_0 = R^*_1/(g+\delta) \text{ with } R^*_{-t} = R^*_{-t+1}/(1+g),\ t = 0,1,2,\ldots,$$

(cf. equation (5) in Hall and Mairesse, 1995). We can interpret R^*_t as the equilibrium growth path for the firm's R&D investments. Hall and Mairesse (1995) use the estimator $R^*_1 = R_1$, which is, however, very vulnerable to measurement errors if the actual investment series R_t for $t \le 1$ deviates from the constant growth rate assumption near $t = 1$ (more distant historic values carry less weight due to discounting). We instead apply a more robust estimator by averaging investment observations in the neighborhood of $t = 1$: $R_1^* = 1/T\sum_t R_t$; i.e., the average R&D investment for the firm using all available data sources.[3] Here *T* is the number of observations on the given firm, whereas the summation is over all *t* where data are available. This estimator is obviously less influenced by random fluctuations in the observed investment series. R&D capital intensity, *rk*, is calculated as the R&D capital stock per man-hour, where the latter is the sum of all man-hours in the firm.

The two variables, *coopf* and *coopu*, indicate whether the firm cooperated with another firm (*coopf*) or with a university or research institute (*coopu*) when carrying out R&D during the

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[2] More than 60 percent of total R&D expenditures are made up of labor costs.

[3] We use all available data on the firm's R&D investments from the biannual 1993–1999 R&D surveys, and the annual 2001–2005 R&D surveys. Although the sample we analyze in this paper is restricted to 1999–2004, we also utilize the out-of-sample data to estimate the initial R&D capital stock, if available for the given firm.

last three years. The SkatteFUNN subsidy, *SFS*, is the tax deductions obtained by the firm as a result of participation in SkatteFUNN. It is deflated by the same index as R&D investments. The dummy variable *d_SFS* indicates whether the firm obtained a SkatteFUNN subsidy in at least one year during the corresponding subperiod. These two variables have positive values only for the second subperiod, i.e., 2002–2004, because SkatteFUNN was introduced in 2002.

For each firm, we distinguish between two types of employees: those with academic education (corresponding to a Master or PhD level of education) and those without. We assume that the former group is highly relevant to R&D activity in the firm. The variable *ac* is defined as the number of man-hours worked by employees with academic education divided by the total number of man-hours in the firm.

There are 3896 and 4655 firms in the 2001 and 2004 innovation surveys respectively. After merging them and excluding firms with incomplete information on the variables of interest, we obtain a reduced unbalanced panel of 2476 firms. Keeping only firms included in both surveys gives us a balanced panel of 1689 firms. One should note that as a result of our choices, the final sample contains a high percentage of medium to large firms and firms in manufacturing and services, compared with the whole population.

Table 2. Mean values of key variables

	1999–2001	2002–2004
Number of firms	1689	1689
rk	0.12 (0.35)	0.12 (0.38)
ac	5.9%	6.4%
Share of firms with *d_R = 1*	39.8%	53.6%
rk | *d_R = 1*	0.26 (0.51)	0.22 (0.50)
ac| *d_R = 1*	9.3%	9.0%
Share of firms with *all SFS* > 0	–	10.5%
Share of firms with *d_SFS = 1*	–	36.2%

Note: Standard deviation in parenthesis. All means are over three year periods. *all SFS > 0* indicates that the firm obtained SkatteFUNN subsidy each year during the corresponding three-year period.

3.2 Descriptive statistics on R&D, innovations and patents

For our sample of firms, Table 2 reports the mean (and standard deviation) for R&D capital intensity, *rk*, and the share of man-hours worked by employees with academic education, *ac*, in the two subperiods. We compute these measures both for the total sample of firms and for the subsample of firms that had some R&D activity during the relevant subperiod (*d_R = 1*).

Not surprisingly, the share of man-hours worked by employees with academic education, *ac*, is higher for the firms that invest in R&D. Moreover, more firms invested in R&D (*d_R = 1*) in the second subperiod; i.e., about 40 percent in 1999–2001 versus about 54 percent in 2002–2004. However, with respect to R&D capital intensity, the R&D projects in the second subperiod seem to be smaller than in the first one. Turning to the SkatteFUNN variables, we see that 10.5 percent of the firms in the sample received a tax subsidy each year in 2002–2004 (*all SFS* > 0). The share of firms who received a subsidy at least once during 2002–2004 (*d_SFS = 1*) is much higher; i.e., 36.2 percent.

Table 3. The share of innovative firms by the type of innovation and patenting, percent

	1999–2001	2002–2004
New product for the firm (*inpdt*)	41.2	36.7
New product for market (*inmar*)	18.6	19.5
New production process (*inpcs*)	33.3	22.4
Applied for a patent (*d_patent*)	13.9	13.9
inpdt | *d_R* = 1	81.0	61.6
inmar | *d_R* = 1	39.4	33.9
inpcs | *d_R* = 1	62.2	38.4
patent | *d_R* = 1	28.7	23.3
inpdt | *d_SFS* = 1	–	65.8
inmar | *d_SFS* = 1	–	38.6
inpces | *d_SF*S = 1	–	39.9
d_patent | *d_SFS* = 1	–	24.6

Note: 1689 firms in each subperiod.

Table 3 gives information about the firms' innovation and patenting activities in 1999–2001 and 2002–2004. The first group of rows reports, separately for each subperiod, the share of innovative firms by different types of innovations and patent application. The next two groups of rows report the share of innovative firms in the two subsamples—the firms carrying out some R&D activity (*d_R = 1*) and the SkatteFUNN firms (*d_SFS = 1*), respectively. One can see that the most frequent type of innovation for Norwegian firms is a new product for the firm, followed by a new production process. Less than 20 percent of these firms innovate in the form of a new product for the market and only about 14 percent apply for a patent. Firms with positive R&D investments and SkatteFUNN firms are more innovative than other firms in both subperiods.

4. Methods

In this section we describe the models we use to study the effects of SkatteFUNN on patenting and different types of innovations. The dependent variable, Y_t, is a binary variable that either takes the value 1 (“success”) or 0 (“failure”). With reference to the variable definitions in Table 1, we will study the following four types of innovations: (i) $Y_t =$ “*d_patent*”, (ii) $Y_t =$ “*inpdt*”, (iii) $Y_t =$ “*inmar*”, and (iv) $Y_t =$ “*inpcs*”. In the case (i), $Y_t = 1$ means that the firm applied for at least one patent in subperiod *t*. In the cases (ii)–(iv), $Y_t = 1$ means that the corresponding type of innovation occurred in subperiod *t*. The time index *t* takes two values: *t = 1* refers to the subperiod 1999–2001 (the three years before the introduction of SkatteFUNN), while *t = 2* refers to the subperiod 2002–2004 (the three years following the introduction of SkatteFUNN in 2002).

The main purpose of our analysis is to estimate the causal effect of SkatteFUNN on the probability of the various types of innovations. Conceptually, one can think of innovations as the output of a production function, with R&D capital as an input factor. The impact of the tax credit on the innovation output of the firms then depends on two things: (i) how much the tax credit increases R&D investments compared with the (hypothetical) situation without any tax credit, and (ii) whether this (marginal) investment leads to an innovation or not. Ideally, we should be able to observe for each firm (i) and (ii). In practice, however, we only observe whether a firm participates in SkatteFUNN or not (*d_SKF*), and whether it innovates or not (Y_t). If firms that have R&D projects with a high *a priori* probability of being successful also have the highest probability of participating in SkatteFUNN, *d*_SKF will be an endogenous variable due to self-selection based on unobservables. Hence, to identify causal effects we need to identify sources of exogenous variation in *d_SKF*.

Before proceeding to the formulation of empirical models, it is useful to consider the following question: in what way may SkatteFUNN change the behavior of a firm? One obvious answer is: by reducing the marginal cost of R&D. However, because the tax credit is limited to project costs of up to 4 million NOK per year, only the firms that would have invested less than 4 million NOK in R&D in the absence of SkatteFUNN have their marginal cost reduced. Another way SkatteFUNN may affect a firm’s behavior is when the firm is liquidity constrained. Then the tax credit may finance R&D investments that may have been profitable also in the absence of the scheme (see Hall, 2002, for a discussion of the importance of financing constraints for R&D investments).[4] These arguments suggest that the firms whose behavior is affected by SkatteFUNN either have their marginal costs of R&D reduced *or* are liquidity constrained. Clearly, firms that do not change their behavior because of SkatteFUNN may also participate in the scheme (and are thus included in the "treatment group"), e.g., firms whose R&D investments are not liquidity constrained and regularly exceed 4 million NOK.

The above discussion highlights an important aspect of the SkatteFUNN scheme—the average effect of SkatteFUNN on the firms that participate in the scheme ("the average treatment effect on the treated") is a weighted average of 0 (the contribution from participants whose behavior is not affected) and the average effect among participants who increase their R&D as a result of the tax credit. On the other hand, firms that do not participate ("the control group") do so because the scheme does not give them sufficient incentive to change their behavior. The latter group is very heterogeneous and comprises firms where the demand for R&D is locally inelastic (possibly due to fixed costs or indivisibilities in R&D investments), and firms that do not bother to participate in SkatteFUNN even if they may be eligible for tax credits.[5]

Our empirical analyses are based on three different versions of logistic regression. The first version should be considered as merely providing descriptive statistics. Here Y_t is regressed on a vector of explanatory variables, X_t:

(1) $$\Pr(Y_t = 1 \mid X_t) = \frac{1}{1+\exp(-X_t\beta)}.$$

That is, (1) is a standard logit model, where $\Pr(Y_t = 1 \mid X_t)$ denotes the probability of "success" for a given firm in period *t* given X_t, where X_t is a (row) vector of independent

[4] Most government revenue loss is not in the form of reduced taxes, but payment of grants to firms that are not in a tax position. Since 2002, roughly 75 percent of the subsidies have been given as grants and this share has been a very stable feature of the scheme irrespective of business cycle fluctuations. In fact, firms that are not in a tax position are significantly overrepresented among the SkatteFUNN firms, even when we control for a broad set of covariates, including industry dummies, firm age, operating margins and value added per man-hour. Since a firm's tax position is likely to be positively correlated with its access to funds, these data strongly suggest that firms with poor liquidity are over-represented among the SkatteFUNN firms.

[5] In fact, about 41 percent of firms that reported positive R&D expenditure in 2004 did not apply for SkatteFUNN tax credits. This suggests that many firms do not bother to apply, even if they are eligible for tax credits.

variables (covariates) and β is the corresponding (column) vector of regression coefficients. The vector X_t contains dummies for subperiod 1 (*d_t = 1*) or 2 (*d_t = 2*); intervals for the number of employees: [10,20), [20,50), [50,100) and $[100,\infty)$; industry (construction, retail trade, transportation services, other services and different manufacturing groups)[6]; whether the firm obtained SkatteFUNN subsidies (*d_SFS*); and whether the firm cooperates with other firms (*coopf)* and/or a university or research institute (*coopu*) when carrying out R&D. Through the interaction terms $d\_SFS \times coopf$ and $d\_SFS \times coopu,$ we also allow the effect of SkatteFUNN to depend on whether the firm has such cooperation or not. Finally, X_t contains two continuous regressors: the share of total man-hours by employees with academic education (*ac*) and R&D capital per man-hour (*rk*).

The date of the variables in X_t refers, in most cases, to the beginning of subperiod *t*. For example, *rk* in subperiod *t = 1* refers to the R&D capital per man-hour in 1999. We choose this dating to reduce the potential endogeneity problem that occurs if the right-hand side variables can be adjusted as a consequence of changes in the dependent variable, Y_t. For example, the firm can increase its R&D investment or initiate a joint research project with another firm as a consequence of an innovation. The one exception to this dating convention regards the dummy variable *d_SFS*, which is one if the firm gets SkatteFUNN subsidies *during* the three year period *t*, leading to a potential problem of simultaneous causality.

One obvious shortcoming of specification (1) is that it does not take into account the persistence of innovation activities at the firm level; i.e., that the dependent variable, Y_2, may depend on Y_1 (given the explanatory variables X_2).[7] For example, we expect, *ceteris paribus*, that the probability of innovating in the second subperiod ($Y_2 = 1$) is larger for firms that innovated in the first subperiod ($Y_1 = 1$) than for those that did not ($Y_1 = 0$).

Valid statistical inferences in the framework of equation (1) require that *d_SFS* is independent of Y_t given the covariates, X_t (i.e., conditional independence). This assumption will not be fulfilled if the firms that *independently of* SkatteFUNN would have had the highest number of

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[6] All industry definitions and the definition of 11 manufacturing groups are based on NACE-codes, SN2002.

[7] Earlier studies have shown that innovation is a quite persistent feature of firms cf. Peters (2007).

patents or innovations also have the highest probability of participating in SkatteFUNN (given the observable exogenous variables).

In our second econometric specification, we attempt to address the self-selection problem by assuming that:

(2) $$\Pr(Y_2 = 1 \mid X_2, Y_1) = \frac{1}{1 + \exp\{-(X_2\beta + Y_1\alpha_1 + (d\_SFS \times Y_1)\alpha_2)\}},$$

where we model the probability of success in subperiod 2 (the probability that $Y_2 = 1$) conditional on the dependent variable in subperiod 1, Y_1, and the explanatory variables in subperiod 2, X_2. In addition, we include an interaction effect between the lagged dependent variable and SkatteFUNN, $d\_SFS \times Y_1$. The interaction term allows the effect of SkatteFUNN to depend on whether the firm had patents/innovations in the previous subperiod (i.e., it depends on Y_1). The validity of specification (2) rests on the assumption that the firms that obtained SkatteFUNN in period 2 constitute a randomized sample from the population of all firms given the value of the independent variables X_2 *and* the lagged value of the dependent variable, Y_1. Thus, the SkatteFUNN firms are allowed to be a self-selected subsample based on the previous outcome of the dependent variable.

Even if the conditional independence assumption behind (2) is weaker than for (1), it may still not be valid. This may be the case if the decision to apply for SkatteFUNN (or to accept the application) is based on the (unobserved) probability of success for already ongoing projects. Thus, there may be simultaneous causality that cannot be accounted for simply by conditioning on the lagged dependent variable.

To account for simultaneous causality we propose a third and more elaborate econometric specification, which is a generalization of (2) in two ways. First, the binary variable *d_SFS* is allowed to be endogenous in the sense that an unobserved variable that influences Y_2 is also allowed to influence the outcome of *d_SFS*. Second, we allow unobserved heterogeneity in the effects of SkatteFUNN by letting the coefficients of *d_SFS*—inclusive of the interaction terms—to be random coefficients (and hence vary across firms). The latter extension is warranted by the discussion at the beginning of this section, where we argued that the treatment effect of SkatteFUNN is not homogeneous across all potential participants in the scheme.

To present this model more formally, let X^* be a continuous latent index, such that $d\_SFS = 1$ if the value of X^* is larger than 0:

(3)
$$d\_SFS = \begin{cases} 1 & \text{if } X^* > 0 \\ 0 & \text{else} \end{cases}.$$

Furthermore, we assume that:

(4)
$$X^* = Z^{(1)}\gamma_1 + \varepsilon^{(1)},$$

where $Z^{(1)}$ is a row-vector of exogenous or predetermined variables that determine the probability that $d\_SFS = 1$, γ_1 is a fixed vector of (unknown) parameters, and $\varepsilon^{(1)}$ is normally distributed with expectation 0 and variance 1. The equations (3) and (4) thus represent a standard probit model for the binary dependent variable *d_SFS.* In our specification of $Z^{(1)}$ we include all variables in X_t except the (endogenous) variables that involve *d_SFS*. In addition, we include dummies for the region, the lagged innovation variable, Y_1, and a binary variable *taxposition*, which is 1 if the firm is in a tax position (i.e., pays taxes) in the beginning of subperiod 2; i.e., in 2002. The variables in $Z^{(1)}$ are thus as follows:

$Z^{(1)}$ *= (1, dummies for employment intervals, industries and regions, ac, rk, coopf, coopu, taxposition,* Y_1*).*

The outcome of the innovation variable Y_2, is also assumed to be determined by a probit model:

(5)
$$Y_2 = \begin{cases} 1 & \text{if } Y^* > 0 \\ 0 & \text{else,} \end{cases}$$

where:

(6) $$Y^* = Z^{(2)}\gamma_2 + S(\beta + \eta) + \varepsilon^{(2)}.$$

In equation (6), $Z^{(2)}$ includes the same variables as $Z^{(1)}$, except *taxposition* and the regional dummies. That is:

$Z^{(2)}$ = *(1, dummies for employment intervals and industries, ac, rk, coopf, coopu, Y_1).*

Furthermore, the vector *S* contains the endogenous variables that involve *d_SFS*:

$$S = (d\_SFS,\ d\_SFS \times coopf,\ d\_SFS \times coopu,\ d\_SFS \times Y_1).$$

Moreover, γ_2 and β are fixed regression coefficients, η is a random coefficient vector with expected value 0, $\varepsilon^{(2)}$ is an additive error term with expectation 0 and variance 1. The vector $(\varepsilon^{(1)}, \varepsilon^{(2)}, \eta')$ is assumed to have a multinormal distribution with expectation 0 and an unrestricted covariance matrix; except for the identifying restrictions that $\varepsilon^{(1)}$ and $\varepsilon^{(2)}$ both have variance 1.

Models (3)–(6) generalize Model (2) in two important ways. First, the additive error term, $\varepsilon^{(1)}$, in the equation that determines participation in SkatteFUNN, is allowed to be correlated with the additive error term, $\varepsilon^{(2)}$, in the equation that determines the latent innovation variable Y^*. Secondly, we allow for heterogeneity in the effects of the endogenous explanatory variables through the vector of random slope coefficients η.

The variable *taxposition* and the regional dummies could be interpreted as "instruments"; i.e., variables that are supposed to affect the participation in SkatteFUNN but not the probability of innovations *per se* (they are excluded from $Z^{(2)}$). The validity of these exclusion restrictions will be discussed further in Section 5.

If Y^* were a directly observable variable, Models (3)–(6) would be a special case of the general ordered probit model analyzed by Dagsvik et al. (2006), and estimation could be carried out by the maximum likelihood methods derived there. However, because Y^* is not observable—we only observe the binary variable Y_2—the methods in Dagsvik et al. (2006) must be modified. Our approach consists of two steps. In step one, we estimate the probit-model (3)–(4) in the traditional way. In step two, given the estimates of γ_1 from the first step, we reformulate (6) in a way similar to that in Dagsvik et al. (2006):

$$(7) \qquad Y^* = Z^{(2)}\gamma_2 + S\beta - S\lambda(d\_SFS)\rho - \lambda(d\_SFS)\xi + \varepsilon^*,$$

where the error term ε^* has conditional expectation equal to 0 given $Z^{(2)}$ and *S*. In (7), ρ is an unknown parameter vector, ξ is an unknown parameter, and $\lambda(d\_SFS)$ is an inverse Mills ratio (depending on the estimates of parameters γ_1 obtained in the first step). See, e.g., Heckman (1976):

$$(8) \qquad \lambda(d\_SFS) = \begin{cases} \dfrac{\phi(-Z_t^{(1)}\gamma_1)}{\Phi(-Z_t^{(1)}\gamma_1)} & \text{if } d\_SFS = 0 \\ \dfrac{-\phi(-Z_t^{(1)}\gamma_1)}{1-\Phi(-Z_t^{(1)}\gamma_1)} & \text{if } d\_SFS = 1. \end{cases}$$

In (8), $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability density and cumulative distribution function, respectively. By postulating a logistic distribution for ε^*, we obtain a logit model for Y_2. The corresponding logit estimates of γ_2 and β can be interpreted as pseudo maximum likelihood estimates, cf. Gourieroux at al. (1984).

5. Empirical results

5.1 Which firms participate in SkatteFUNN?

We consider first the estimation of the SkatteFUNN-participation equation (4). We will further use the results of this estimation to calculate the function $\lambda(\cdot)$, defined in (8), to estimate the innovation equation (7). The problems we address in this subsection have many similarities with Blanes and Busom (2004), who study participation in R&D subsidy programs for Spanish manufacturing firms. Like Blanes and Busom (2004), we include measures of the skill of the employees, lagged R&D activity, firm size and financing constraints as explanatory variables in the participation equation.

A key role in our estimation is assigned to the variable *taxposition* and the regional indicators, which are contained in $Z^{(1)}$, but not in $Z^{(2)}$. The exclusion restrictions contribute to identifying the effects of participating in SkatteFUNN: For a given value of $Z^{(2)}$, variation in the excluded variables contributes to *exogenous* variation in S. The identification, of course, requires that regional location or whether a firm is in a tax position or not, has no direct effect on innovation probability.

The results in Table 4 show that three of the regional dummies (south, west, and mid-Norway) are significant and have a positive sign (the coefficient of the capital region Oslo is 0 *a priori*). Norway has a long tradition of taking regional considerations into account when deciding on policies, with a bias in favor of remote and sparsely populated regions. This may also be relevant for SkatteFUNN, even if the scheme is open to all firms. The reason is that firms apply for SkatteFUNN funding through regional offices of Innovation Norway, a government body that helps firms in their innovation activities. These regional offices may differ in their ability to support firms in getting their applications approved by the Norwegian Research Council (cf. Appendix A). On the other hand, there is little reason to believe that heterogeneity in the resources of the regional offices of Innovation Norway has a direct effect on the probability of success of the research projects. Nor do we find that the regional dummies are significant in any of the innovation equations (when carrying out joint likelihood ratio tests). Thus, the region of the firm seems to have no direct effect on the probability of innovating.

From Table 4 we also observe a significant *negative* relation between SkatteFUNN and the variable *taxposition*. A plausible explanation, as suggested in our discussion at the beginning of Section 4, is that participation in SkatteFUNN could be motivated by the liquidity situation of the firm. Another explanation could be that *taxposition* is negatively correlated with the firm's tax planning abilities, including knowledge about and active use of tax reducing schemes such as SkatteFUNN.[8] In any case, this variable should not be informative about the probability of innovating *per se*, given the exogenous and predetermined explanatory variables of the model.

The main rationale for the "exclusion restriction" with regard to *taxposition* is that, while financing constraints may restrict a firm's R&D investments, it is not a production factor *per se*. That is, given the vector of productive inputs at the *beginning* of the three-year period

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[8] This interpretation was suggested to us by an accountant who had experience in auditing firms subsidized by the SkatteFUNN scheme.

(including R&D capital stock), information about whether or not the firm is liquidity constrained (at that point in time) does not help us to predict its innovation probability during the corresponding subperiod. Given that the regional dummies provide valid identifying restrictions (cf. the discussion above), it is also possible to test this assumption by including *taxposition* as an explanatory variable in the innovation equations. In neither of the equations do we reject the hypothesis that the coefficient of *taxposition* is zero.

Table 4. Probit estimates for the probability of *d_SFS* = 1

Variable	Estimate	S.E.
Dummy for:		
10–19 employees	–0.36	0.23
20–49 employees	–0.08	0.22
50–99 employees	–0.10	0.22
≥ 100 employees	–0.27	0.21
Construction	0.38	0.26
Retail trade	0.07	0.24
Transport	–0.30	0.19
Services	0.55	0.18
Industry A (Nace 15–16)	0.65	0.18
Industry BC (Nace 17–19)	0.64	0.23
Industry D (Nace 20)	0.62	0.23
Industry E (Nace 21–22)	0.16	0.19
Industry FGH (Nace 23–25)	0.91	0.21
Industry I (Nace 26)	0.48	0.24
Industry J (Nace 27–28)	0.69	0.19
Industry K (Nace 29)	1.09	0.21
Industry L (Nace 30–33)	0.80	0.20
Industry M (Nace 34–35)	0.73	0.19
Industry N (Nace 36–37)	1.20	0.23
East coast	0.10	0.12
East inland	0.11	0.17
South	0.64	0.12
West	0.41	0.12
Mid-Norway	0.39	0.15
North	0.29	0.18
ac	1.18	0.35
rk	0.13	0.07
coopf	0.30	0.10
coopu	0.39	0.12
taxposition	–0.16	0.07
Y_{t-1} (lagged dummy for innovations)	0.44	0.08
Constant	1.19	0.26

Note: There are seven main regions in Norway, where the capital region Oslo is made the reference.

The results in Table 4 also show that past innovation activities, Y_{t-1}, have a huge impact on participation in SkatteFUNN—the dummy for lagged innovations is clearly the most significant variable in the table. The share of man-hours worked by persons with academic education, *ac,* and both types of cooperation, *coopf* and *coopu*, also have large impacts on the participation probability. There is considerable heterogeneity across different industries, with firms from some of the manufacturing industries having, *ceteris paribus*, the highest probability of participating in SkatteFUNN.

5.2 Estimation results for innovations and patents

Tables 5–8 present the results for the four different dependent variables and three different versions of the econometric model. The tables focus on the most important explanatory variables. We do not report results for control variables such as firm size and industry. Our estimates regarding these variables are in line with results well established elsewhere in the empirical literature: firms with more employees have a higher probability of patenting or innovating than other firms, while manufacturing industries are those with the highest probability of patent applications and innovations.

Table 5. Logistic regression. Dependent variable: Y_t = "d_patent" (patents)

Variable*	logit		conditional logit		conditional logit with selection	
	Est.	S.E.	Est.	S.E.	Est.	S.E.**
Dummy for:						
1999–2001	–3.45	0.40	–	–	–	–
2002–2004	–3.55	0.40	–3.55	0.51	–4.12	0.77
ac	2.39	0.47	0.75	0.88	0.51	0.94
rk	0.85	0.11	0.39	0.16	0.29	0.22
coopf	0.62	0.13	0.43	0.22	0.49	0.24
coopu	0.80	0.14	0.61	0.26	0.80	0.27
d_SFS	0.24	0.23	0.44	0.30	1.10	1.18
d_SFS × *coopf*	0.31	0.24	0.24	0.30	0.23	0.31
d_SFS × *coopu*	0.15	0.22	0.10	0.29	0.05	0.29
d_SFS × Y_{t-1}	–	–	0.07	0.35	0.16	0.40
Y_{t-1}	–	–	2.54	0.26	2.54	0.31
Number of firms in the sample	2467		1527		1527	

* Size and industry dummies are included in the analyses but not reported here.

** S.E. calculated conditional on the step-1 estimates.

Table 5 shows the results for patents. We first note that the estimate of the coefficient of the time dummy of the second period is lower than for the first one in the (standard) logit model. This corresponds to a drop of approximately 10 percent in total patent applications in Norway between these two subperiods. In the standard logit model, the share of employees with academic education, *ac*, and R&D capital intensity, *rk*, are also very significant explanatory variables. This result is typical in the literature; cf. Crepon et al. (1998), Parisi et al. (2006), and Griffith et al. (2006).

The coefficient of *d_SFS* is not significant in any of the three model specifications reported in Table 5. However, a joint hypothesis of whether *all* the parameters involving SkatteFUNN-variables are zero is rejected in the standard logit model, with a p-value of 0.01. The conditional logit model that allows *d_SFS* to be endogenous (cf. the two last columns) gives estimates for the effect of SkatteFUNN that are less significant than in the simple conditional logit model. For example, a joint test that *d_SFS* has zero effect on patenting yields a p-value of 0.63. Thus there is no evidence that the SkatteFUNN scheme affects the probability of patent applications. We can also see that by conditioning on Y_{t-1}, much of the explanatory power of *rk* and *ac* disappears compared with the standard logit model. On the other hand, the dummies for cooperation *coopf* and *coopu* are very significant in all the three model variants, especially cooperation with a research institute (*coopu*).

Table 6. Logistic regression. Dependent variable: Y_t = "inpdt" (new product for the firm)

Variable*	logit		conditional logit		conditional logit with selection	
	Est.	S.E.	Est.	S.E.	Est.	S.E.**
Dummy for:						
1999–2001	–1.44	0.28	–	–	–	–
2002–2004	–2.07	0.28	–2.93	0.47	–2.72	0.53
ac	1.12	0.45	1.60	0.71	2.30	0.82
rk	0.74	0.19	–0.01	0.14	–0.02	0.17
coopf	1.19	0.12	0.47	0.21	0.53	0.22
coopu	0.67	0.14	0.23	0.26	0.27	0.28
d_SFS	1.52	0.17	1.68	0.22	1.48	0.86
d_SFS × *coopf*	0.19	0.21	0.48	0.25	0.44	0.27
d_SFS × *coopu*	–0.03	0.23	0.17	0.27	0.07	0.29
d_SFS × Y_{t-1}	–	–	–0.92	0.28	–1.20	0.31
Y_{t-1}	–	–	1.91	0.17	2.32	0.25
Number of firms in the sample	2467		1484		1484	

* Size and industry dummies are included in the analyses but not reported here.

** S.E. calculated conditional on the step-1 estimates.

Let us now turn to the results for innovations reported in Tables 6–8. One can observe a general pattern for all three types of innovations. From the standard logit model we find that the share of academics (*ac*) and R&D capital per man-hour (*rk*) are very significant variables. In the two conditional logit models, however, we find no significant impact of *rk* on the probability of innovating. The explanation may be that the value of the lagged dependent variable Y_{t-1} also incorporates the effect of *rk,* because these variables are highly correlated as evident from the standard logit model. Again, we find that the coefficient of Y_{t-1} is highly significant and positive and of a similar magnitude in the two conditional models. For all innovation types, we find that cooperation with another firm (*coopf*) is a significant explanatory variable in contrast to the case of patenting, where *coopu* (cooperation with a research institute) is more influential. This difference may reflect that innovations in general are "closer to the market" than patenting, where academically oriented collaboration is more important.

Table 7. Logistic regression. Dependent variable: Y_t = "inmar" (new product for the market)

Variable*	logit		conditional logit		conditional logit with selection	
	Est.	S.E.	Est.	S.E.	Est.	S.E.**
Dummy for:						
1999–2001	–3.21	0.31	–	–	–	–
2002–2004	–3.05	0.32	–3.67	0.47	–3.52	0.55
ac	1.49	0.38	1.34	0.62	1.73	0.73
rk	0.01	0.03	0.15	0.14	0.19	0.15
coopf	0.87	0.11	0.57	0.19	0.61	0.50
coopu	0.60	0.13	0.43	0.23	0.72	0.46
d_SFS	1.25	0.16	1.51	0.20	1.10	0.84
d_SFS × *coopf*	0.10	0.18	0.13	0.21	0.11	0.24
d_SFS × *coopu*	0.10	0.19	0.15	0.22	0.16	0.25
d_SFS × Y_{t-1}	–	–	–1.16	0.29	–1.30	0.34
Y_{t-1}	–	–	2.09	0.21	2.39	0.27
Number of firms in the sample	2467		1484		1484	

* Size and industry dummies are included in the analyses but not reported here.

** S.E. calculated conditional on the step-1 estimates.

The SkatteFUNN dummy is clearly significant in the standard logit and conditional logit models, but not in the model where *d_SFS* is allowed to be endogenous. The interaction effect between *d_SFS* and cooperation with another firm (*d_SFS* × *coopf*) is significant at the 95 percent level in the conditional logit model, and 90 percent level in the conditional model with selection. The estimated interaction effect *d_SFS* × Y_{t-1} is negative and significant in both the conditional models: if the firm was innovating *before* getting a SkatteFUNN subsidy, the effect of SkatteFUNN is weaker. Likelihood ratio tests of the joint hypothesis that all the variables involving *d_SFS* have corresponding coefficients equal to zero (4 degrees of freedom in the standard logit model, and 5 degrees of freedom in the conditional logit models) were clearly rejected in all the model variants, with p-values close to zero.

Table 8. Logistic regression. Dependent variable: Y_t = "inpcs" (new production process)

Variable*	logit		conditional logit		conditional logit with selection	
	Est.	S.E.	Est.	S.E.	Est.	S.E.**
Dummy for:						
1999–2001	–1.71	0.27	–	–	–	–
2002–2004	–2.44	0.28	–2.57	0.45	–3.71	0.54
ac	0.60	0.39	0.65	0.58	1.42	1.13
rk	0.13	0.09	–0.10	0.13	0.13	0.15
coopf	0.85	0.11	0.47	0.18	0.61	0.20
coopu	0.63	0.13	0.43	0.21	0.47	0.26
d_SFS	1.27	0.16	1.44	0.19	1.88	0.87
$d\_SFS \times coopf$	–0.01	0.18	0.15	0.21	0.13	0.24
$d\_SFS \times coopu$	–0.14	0.19	–0.10	0.22	0.15	0.25
$d\_SFS \times Y_{t-1}$	–	–	–0.98	0.24	–1.30	0.34
Y_{t-1}	–	–	1.81	0.17	2.31	0.25
Number of firms in the sample	2467		1484		1484	

* Size and industry dummies are included in the analyses but not reported here.

** S.E. calculated conditional on the step-1 estimates.

From the very significant coefficient estimate of the lagged dependent variable, Y_{t-1}, for all four types of innovation (see Tables 5–8) we can infer that innovation is a rather persistent characteristic of a firm. This is illustrated by the estimated conditional probabilities of innovation in Table 9 (based on the results reported in Tables 5–8). For example, the conditional probability of patenting in subperiod *t,* given that the firm applied for a patent in subperiod *t–1,* is 0.54 (S.E. = 0.05) if *d_SFS = 0* and 0.74 (S.E. = 0.03) if *d_SFS = 1*. The corresponding numbers when $Y_{t-1} = 0$, i.e., the firm did not apply for patents in subperiod *t*–1, are much smaller: 0.04 (S.E. = 0.01) and 0.10 (S.E. = 0.01), respectively. For other types of innovation we observe the same pattern. However, the pairwise differences obtained by comparing *d_SFS = 0* with *d_SFS* = 1 cannot be interpreted as effects of SkatteFUNN, because they reflect a gross effect—firms with *d_SFS* = 1 have, on average, different values for the other explanatory variables in X_t, which have been "marginalized out" to obtain the estimated conditional probabilities reported in Table 9.[9]

Let us now look at the estimates for the partial effects of SkatteFUNN on the different types of product and process innovations. We will restrict this part of the analysis to the model with

[9] If *Z* denotes the vector of variables that are "marginalized out", then, for example:
$\Pr(Y_t = 1 \mid Y_{t-1} = 1, d\_SFS = 0) = \sum_z \Pr(Y_t = 1 \mid Y_{t-1} = 1, d\_SFS = 0, Z = z)\Pr(Z = z \mid Y_{t-1} = 1, d\_SFS = 0)$.

selection specified in (5)–(8), where *d_SFS* specified as an endogenous variable, and to two types of innovations: a new product for the firm and a new production process. For these types of innovations, we clearly reject the joint hypothesis that all the variables involving *d_SFS* have zero coefficients.

Table 9. Estimated probabilities of innovation conditional on previous innovation activity and participation in SkatteFUNN*

	Type of innovation			
Probability	Patent	New product for the firm	New product for the market	New production process
$\Pr(Y_t = 1 \mid Y_{t-1} = 1, \text{d\_SFS} = 0)$	0.54	0.65	0.61	0.56
$\Pr(Y_t = 1 \mid Y_{t-1} = 1, \text{d\_SFS} = 1)$	0.74	0.90	0.79	0.74
$\Pr(Y_t = 1 \mid Y_{t-1} = 0, \text{d\_SFS} = 0)$	0.03	0.16	0.10	0.14
$\Pr(Y_t = 1 \mid Y_{t-1} = 0, \text{d\_SFS} = 1)$	0.10	0.66	0.48	0.49

* Based on conditional logit with selection.

Estimates of the partial effects of SkatteFUNN subsidies on the probability of a new product for the firm are presented in part (1) of Table 10. We see that a significant positive effect is found only for firms that did not innovate in the previous subperiod *and* cooperated with another firm. For example, for a representative firm with such cooperation and no innovation in the previous subperiod (and average values of all other variables), the effect of a change in the value of *d_SFS* from 0 to 1is given by a logit coefficient of 1.92 (S.E. = 0.90).[10] This change increases the probability of a new product for the firm by 0.26 from 0.16 (see Table 6 and Table 10). In the case of cooperation with both, i.e., another firm and a research institute, this probability increases by 0.27. On the other hand, if the firm, *ceteris paribus*, had such an innovation in the previous subperiod, the effect of SkatteFUNN becomes insignificant.

The partial effects of SkatteFUNN subsidies on the probability of a new production process are presented in part (2) of Table 10. We see that these effects are highly dependent on the lagged dependent variable, Y_{t-1}. For a firm with no cooperation and no process innovations in the previous subperiod, the estimated effect is given by a logit coefficient of 1.88 (S.E. = 0.87), which is significant at the 5 percent level. For a representative firm, this means an increase in the probability of a process innovation equal to 0.23 (from 0.14) as a result of the SkatteFUNN subsidy (see Table 8 and Table 10). If the firm also cooperated with another

[10] Formally, this is the change in the log odds $\ln(p/(1-p))$, where p is the probability of innovation.

firm or a research institute the probability of a process innovation increases by 0.24 (and by 0.26 in the case of cooperation with both another firm and a research institute). On the other hand, if the firm, *ceteris paribus*, had innovations in the previous subperiod, none of the partial effects are significant.

Table 10. Partial effects of SkatteFUNN on the probability of innovating (new product for the firm and process innovation)

Conditional on	(1) New product for the firm				(2) New production process			
	Share of obs.	Estimated logit	S.E.	Changes in probability	Share of obs.	Estimated logit	S.E.	Changes in probability
$Y_{t-1}=0, coopf=0, coopu=0$	0.48	1.48	0.86	0.20	0.52	1.88	0.87	0.23
$Y_{t-1}=0, coopf=1, coopu=0$	0.02	1.92	0.90	0.26	0.03	2.01	0.90	0.24
$Y_{t-1}=0, coopf=0, coopu=1$	0.22	1.55	0.91	0.21	0.18	2.03	0.91	0.24
$Y_{t-1}=0, coopf=1, coopu=1$	0.04	1.99	0.95	0.27	0.04	2.16	0.94	0.26
$Y_{t-1}=1, coopf=0, coopu=0$	0.03	0.28	0.91	0.06	0.06	0.58	0.93	0.14
$Y_{t-1}=1, coopf=1, coopu=0$	0.01	0.72	0.95	0.16	0.02	0.71	0.96	0.17
$Y_{t-1}=1, coopf=0, coopu=1$	0.11	0.35	0.96	0.08	0.08	0.73	0.97	0.18
$Y_{t-1}=1, coopf=1, coopu=1$	0.07	0.79	1.00	0.17	0.06	0.86	1.00	0.21

6. Conclusions

In this paper, we have studied how the Norwegian R&D tax credit scheme, SkatteFUNN, has affected firms' innovation activities. Our results imply that the SkatteFUNN scheme contributes to an increase in the rate of innovation by firms. SkatteFUNN projects contribute to the development of new production processes and to some extent to new products for the firm. Firms that collaborate with other firms are more likely to have successful innovations. However, the scheme does not appear to contribute significantly to innovations in the form of new products for the market or patenting.

Our finding that the SkatteFUNN scheme mainly stimulates innovations in the form of new products for the firm (but not for the market) and new production processes suggests that the scheme does not stimulate innovations that may create significant spillovers among the firms. If we take into account that the majority of firms that are subsidized through the scheme are SMEs, our results may not come as a surprise. Also the scheme has a cap on total subsidies and this feature of the scheme probably limits the possibility of achieving major innovations in new products for the market or patents. For stimulation of these types of innovation, other research policy instruments such as grants from the Norwegian Research Council are probably more relevant.

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Appendix A. SkatteFUNN – background and design

SkatteFUNN is aimed at increasing business expenditure on R&D in Norway and is part of the Norwegian tax system. In the parliamentary discussion on the government white paper for the revised national budget in 2001, a majority in the Storting (parliament) asked the government to design and propose to the Storting a tax incentive to stimulate business R&D activities. It was asked that the system be in line with a proposal suggested by the majority of an expert committee, which was put forward in 2000. The scheme was proposed as part of the tax law for 2002 and approved by the Storting in December 2001. The system was accepted by the ESA in October 2002 and was thus in place for SMEs for the tax year 2002. It was extended to cover all firms for the tax year 2003.

SkatteFUNN is a system with tax credits, implying that firms can deduct from tax payable a certain amount of their R&D expenditures. Firms are entitled to the tax credit as long as the R&D project has been approved by the Norwegian Research Council. If the tax credit exceeds the tax payable by the firm the difference is paid to the firm like a grant. If the firm is not in a tax position at all, the whole amount of the credit is paid to the firm as a negative tax or a grant. This payment is done when the tax authorities have completed their tax assessment, and takes place the year after the actual R&D expenses have occurred.

From 2003, the SkatteFUNN scheme is as follows. For large firms (more than 250 employees, more than 40 million euros in turnover or a balance sheet of more than 27 million euros, and owned by more than 25 percent of a large enterprise), 18 percent of R&D expenses related to an approved project up to a limit of 4 million NOK (approximately 0.5 million euros) is given as a tax credit. Thus, for a large firm the maximum tax relief is $4 \times 0.18 = 0.72$ million NOK (90 000 euros). If the firm has a project that involves collaboration with an approved research institute (according to a list decided upon by the Norwegian Research Council), it can also deduct expenses of a purchase of 4 million NOK in services from this institute so that the amount deductible becomes 1.44 million NOK (180 000 euros). For SMEs, the rate is 20 percent.

Since 2003, the number of projects has varied between 4000 and 6000. Since 2003, the revenue cost for the government has been roughly 1.3 billion NOK annually, of which nearly three quarters has been paid as grants. Around two thirds of the R&D expenses are personnel costs. Roughly 85 percent of all projects approved by the Norwegian Research Council are undertaken by firms with less than 50 employees. In 2004, 13 percent of all manufacturing firms used SkatteFUNN compared to only 1 percent of firms in construction and services. Very few projects are designed as cooperation projects between firms or between firms and a research institute.

When the Storting decided to introduce SkatteFUNN it also included an evaluation of the scheme. More information and the main results of the evaluation can be found in the summary of the final report: http://www.ssb.no/skattefunn/rapp_200802_en.pdf.