Annex 2

Tax incentives for industry-science R&D collaboration

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Introduction

Successful creation of new knowledge often depends on the ability of firms to establish cooperative R&D agreements in order to combine their resources, exploit complementary know-how, and internalize R&D externalities (Katz, 1986; d'Aspremont and Jacquemin, 1988; Kamien et al., 1992).

Governments have long understood the virtues of R&D collaboration and have exempted R&D partnerships from anti-trust legislation. In the European Union, for instance, the Treaty of Rome already contained a notice in article 85(3) that collaborating in R&D is permissive as long as post-innovation rivalry is not blocked. In 1984, the European Commission approved a block exemption for R&D collaborations that also allows joint exploitation of results (see Martin, 1997 for an overview on policy practices in the U.S., Japan and Europe).

In addition, governments often subsidize R&D collaborations. Governments of European Member States maintain subsidy schemes, where grant applications from consortia are preferred over single firm applications. In the recent past, technology transfer from science to industry has attracted the attention of policy makers, and as a result industry-science collaborations are often granted a preferential treatment in public grant systems. It is believed that an enhanced knowledge and technology transfer from science to industry also contributes to the long-run innovativeness and thus competitiveness of the business sector.

The potential benefits of R&D collaborations can be summarized as follows: First, technological spillovers are internalized, thus eliminating the free rider problem within the group of cooperating firms. Second, since R&D often exhibits economies of scale, it might well be that only a consortium of firms has the necessary resources both financially and physically to undertake the ever larger, more complex, and more expensive research projects that are common today. Third, economies of scope also often characterize the R&D process. Hence, synergetic effects and risk pooling can broaden the research horizon of cooperating firms. It can thus be expected that sustaining R&D cooperatives leads to an increase in private R&D activity. Formal economic models show, indeed, that under certain circumstances R&D cooperatives devote more resources to innovative activities than competing firms would. From the ever growing literature

on cooperative R&D can be concluded that cooperative R&D levels exceed non-cooperative levels whenever technological spillovers are large, while the opposite holds for small technological spillovers (see Veugelers 1998 for a survey of theoretical and empirical literature).

This paper discusses the potential impacts of R&D tax credits schemes involving higher tax allowances for firms that collaborate with public research institutions when compared to other tax credit recipients. First, the market failure for R&D and the economics of R&D collaborations are discussed where both theoretical and empirical literature is reviewed. Second, recent literature on effects of R&D policies at the firm level is briefly discussed. The third goal of the paper is the combination of both strands of literature which leads to suggestions on how current R&D tax schemes involving extra tax deductions for companies engaging in industry-science collaborations should be evaluated in European Member States.

Theory

The market failure for R&D investment

The standard argument for governmental intervention in the market for R&D is based on two market failure arguments. First, R&D creates positive, external effects, that is, R&D creates knowledge and as Arrow (1962) hypothesized, something intangible such as knowledge cannot be kept secret to full extent by the original R&D investor. This implies that a private company investing in R&D will not be able to appropriate all returns from its initial investment as knowledge will spill over to rivals and other third parties that subsequently free-ride, i.e. build on the knowledge, without having participated in the investment. This may happen due to the mobility of personnel, but also through many other channels, e.g. joint customers or suppliers (see e.g. Mansfield, 1985). Thus the social benefit of R&D investments is typically much larger than the private return. As, however, firms will only decide on investments with a positive expected private return, many R&D projects that are socially desirable may not be undertaken. This leads to a gap between social and private equilibrium and, consequently, a justification for governmental intervention.

The second market failure argument is typically established due to financing constraints for R&D. If a firm seeks external financial resources for an investment, R&D features several characteristics that make it more difficult or expensive to finance externally than, for instance, investment in tangible assets. For instance, the lion's share of an R&D investment project is sunk cost, as R&D mainly consists of wages for researchers. In contrast to physical capital investment, R&D is not capitalized in the balance sheet of a firm, so that it cannot be used a collateral in credit negotiations with banks. Furthermore, the outcome of an R&D project is typically much more uncertain than the return of investments into physical capital which makes potential lenders also less likely to invest. See e.g. Hall (2002) and Hall and Lerner (2010) for surveys of this strand of literature, or the summary paper on financial constraints for R&D in this report (Annex 3).

Although these are good economic reasons for governments to finance R&D publicly, i.e. financing R&D in universities, and also in form of grants or tax credits to the private companies, it is not straightforward to establish a clear-cut theoretical market failure argument for a preferential treatment of industry-science collaborations within certain schemes. Exempting R&D collaboration from anti-trust legislation can already be seen a policy itself, as the possibility of collaborating in R&D allows firms a) to internalize the potential external effects at least within the consortium of project partners, b) spreads the risk of outcome uncertainty and c) divides the cost of R&D among involved agents.

However, in combination with some empirical evidence from the literature on knowledge and technology transfer between science and industry, arguments for such extra incentives may be made.

As will be outlined below, it seems to be a generally accepted opinion that involvement of universities or other public research institutions concerns more basic research projects and the transfer of more generic knowledge than the "usual" business R&D projects. The idea is that companies seek university collaboration for more fundamental, long-term and possibly strategic R&D projects. Empirical evidence supports this view. Thus, is could be argued that R&D conducted within industry-science collaborations involves projects that are socially more desirable than others, as more basic knowledge is created which expectedly would lead to higher knowledge spillovers, i.e. the social return to these investments is high. From the companies' perspective, however, basic research suffers from worse appropriability conditions than other projects. For instance, without any specific industrial application in mind, the original investor may not be able to take out a patent for protecting the results of the initial investment. In addition, the uncertainty about expected pay-offs of such investments is typically even higher than for other R&D investments, as projects of more basic research are further away from the market and its potential applicability to new products and processes may be largely unknown at time of the investment. This reasoning leads to the conclusion that the market failures due to external effects and financial constraints apply even more for research conducted within industry-science consortia than for other projects making a higher degree of governmental intervention than for other R&D justifiable.

Theory of R&D collaboration

This subsection reviews the theoretical literature on R&D collaboration. The industrial organization literature makes a clear distinction between horizontal collaborations, i.e. among firms in the same industry, versus vertical or diagonal collaboration, i.e. firms in vertically related or non-related industries. As the understanding of mechanisms in horizontal collaborations is key to the other model approaches, the literature on horizontal collaboration is discussed first.

Horizontal R&D collaboration

The question of how and why firms engage in R&D collaborations and how that affects welfare emerged during the 1980s in economic literature (see Veugelers, 1998, for a survey). The industrial organization literature emphasizes the importance of knowledge spillovers in the context of collaborative research (e.g. Katz, 1986, d'Aspremont and Jacquemin, 1988, Beath et al., 1988, De Bondt and Veugelers, 1991, Kamien et al., 1992, Motta, 1992, Suzumura, 1992, Vonortas, 1994, and Leahy and Neary, 1997). Such studies relate decisions to collaborate in R&D to the presence of spillovers and the effects on market performance with respect to profits. Models rely on the fact that returns from R&D are not fully appropriable by the firm, but knowledge leaks out to competitors such that social benefit is higher than private return. This, of course, leads to underinvestment in innovative activity from a social point of view. R&D collaborations are one possibility to internalize such knowledge spillovers and thus increase appropriability of returns within the research consortia. Three main issues with respect to cooperative R&D are considered in the following: coordination, free-riding and information sharing.

Coordination in such models is typically described through joint profit maximization. One finding is that investment in R&D among collaborators increases with the level of spill-over effects. A second result states that if spillovers are high enough, that is, above some critical level, cooperating in R&D will result in higher investment compared to the status of no collaboration (cf. De Bondt and Veugelers, 1991). Cooperating in R&D always increases firms' profitability. Consequently, when spillovers are high enough, firms have an increasing incentive to engage in R&D collaborations, and this should enhance welfare. It should be noted, however, that cost of coordinating R&D is often ignored in these models.

Collaborations bear the inherent risk of free-riding that may distort the stability of cooperation. Partners may free-ride as they could try to absorb knowledge from their partners but conceal their own (see e.g. Shapiro and Willig, 1990, Baumol, 1993, Kesteloot and Veugelers, 1994). Models find that cooperative agreements for being profitable and stable require that involuntarily outgoing spillovers are not too high. This is in contrast with the results on coordination, where profits are higher with larger spillovers. Here the profitability of collaboration increases with the firms' ability to manage the outgoing spillovers in order to protect against possible free-riding of partners.

Some models explicitly account for information sharing among partners that is managing spillovers (e.g. Kamien et al., 1992, Katsoulacos and Ulph, 1998). Katsoulacos and Ulph model the choice of spillovers and find the research joint ventures will always share at least as much information as non-cooperating firms, because research joint ventures maximize joint profits. Another issue for managing spillovers is absorptive capacity. Cohen and Levinthal (1989) point out that incoming spillovers can be used more efficiently (in reducing own cost) when the firm is engaged in own R&D. Engaging in own R&D builds absorptive capacity, that is, the ability of a firm to benefit from the knowledge of others created through R&D activity. Kamien and Zang (2000) take that into account, and find ambiguous results with respect to R&D investment. Yet, collaboration is still the more profitable option.

In conclusion, theory states that non-collaborative R&D levels decrease with magnitude of spillovers, while cooperative investments tend to increase with spillovers, and thus imperfect appropriability of knowledge generating processes increases the benefits from collaborative agreements. If spillovers are above a certain level, the "critical spill-over", co-operative R&D will result in higher investment than non-cooperative R&D. The presence of spillovers increases the incentive for R&D collaboration through the internalization of the positive externality. Kamien and Zang (2000) show that result may no longer hold when absorptive capacity is taken into account, though. Information sharing increases the profitability of R&D cooperation. When spillovers are high enough, collaborating firms will not only invest more in R&D, but are also more profitable than independently researching firms. Welfare is enhanced when spillovers are large enough, but ambiguous when spillovers are low. However, imperfect appropriability also encourages free-riding on R&D performed by other firm.

Theoretical results have initiated a whole debate on the implications of R&D collaborations for antitrust and the treatment of research joint ventures, leaving a favourable policy stance towards this type of cooperation (Ordover and Willig, 1985, Jacquemin, 1988, Shapiro and Willig, 1990). Although it seems to be an important policy conclusion leading to a more lenient policies towards R&D collaborations, it should be stressed that this only holds for co-operation restricted to R&D. If R&D collaboration would facilitate product market collusion, the welfare enhancing results do no longer hold, of course. Hinloopen (2001) is one of the few papers that explicitly model the impacts of subsidies on collaborative and non-collaborative R&D.[1] The policy towards collaboration is not a subsidy, but only the legal opportunity to engage in R&D collaborations. Given this framework, he finds that the incentive to invest in R&D is higher for subsidies than the policy of allowing for collaboration. In a further step, Hinloopen shows that in case of optimally subsidizing cooperative or non-cooperative R&D leads to the same level of R&D activity. This suggests that "[...] sustaining R&D collaboratives is a redundant industrial policy, all else equal." (Hinloopen, 2001: 316)

Vertical and diagonal R&D collaboration

The vast majority of theoretical models deals only with horizontal R&D co-operation, that is, collaboration among competitors, as the joint choice of R&D in combination with product market competition sets an interesting framework for theoretical modelling towards the drivers of such decisions. While this set-up is predominant in theory, it stands in stark contrast to empirical evidence (mostly from surveys such as the Community Innovation Surveys and similar sources): typically, firms' most important collaboration partners are customers, suppliers and universities or other research institutions. Empirically, collaboration with competitors is not found to be a significant case in most countries, at least in terms of frequency of collaborations.

However, the theoretical literature on vertical collaboration including industry-science cooperation is scarce. The reason is that vertical collaboration partners do not impose a negative externality on each other, as they do not compete in the same product market. Thus, the theoretical concerns concerning the trade-offs in cost and benefits of R&D collaborations apply

[1] See also Hinloopen (1997, 2000a, 2000b).

to a lesser extent to vertical collaboration. Firms may engage in vertical R&D collaboration to reduce the cost of R&D, e.g. a firm decides to collaborate with a university as the public research institution may possess "superior" knowledge for certain projects than the firm has internally available. Rather than generating this knowledge in-house, it may be preferable to seek it externally. Furthermore, seeking complementary knowledge may lead to economies of scale and scope which in turn result in increased in-house R&D (see Cassiman and Veugelers, 2006). Similarly to horizontal collaboration, risk sharing arguments concerning the outcome uncertainty of R&D investments are a further motive for engaging in vertical collaboration. Firms would choose to engage in vertical collaboration if the expected benefits outweigh the transaction cost involved. Steurs (1995) is the first paper that extends models of R&D collaboration to inter-industry spillovers. While typical collaboration literature considered only horizontal collaboration, this study analyzes a two-industry, two-firm-per-industry setting. It is assumed that intra-industry and inter-industry spillovers exist. As firms engaging in inter-industry collaboration do not impose a negative externality on each other, it is found that inter-industry collaboration is socially more beneficial than cooperatives whose members come from a single industry. In the Steurs (1995) model, the industries are not related except for the presence of spillovers. This framework is extended by Inkmann (1999) who explicitly models strategic R&D investment in the presence if R&D spillovers between vertically related industries. The R&D investments of the upstream firm affect the production process or quality in the downstream firm which in turn leads to higher demand in the final product market and thus also for the intermediate good. In equilibrium, vertical collaboration maximizes the profits of the participating firms, and leads to increased R&D in the economy. A similar model is presented in Atallah (2000) where vertical R&D collaboration unambiguously leads to higher R&D and welfare in the economy. These papers are able to explain the empirical finding that vertical collaborations are much more frequent than horizontal collaborations in reality.

The inter-industry collaboration as referred to in the Steurs (1995) study can be interpreted as industry-science collaboration. Although the paper labels the agents as two firms in non-related industries, the term "firm" could be replaced by university, as the two agents are neither related horizontally nor vertically in any market. There are simply knowledge spillovers possible between them. This to a large extent applies to the relationship between a firm and a university within collaborative agreements. As these "diagonal" collaborations create a higher social welfare than other types of collaboration, it may be argued that it is desirable to foster the emergence of such consortia in reality. Consequently, we now review the empirical evidence on R&D collaboration. For reaching policy conclusions, it is necessary to find empirical support for the above mentioned theoretical effects.

Empirical Evidence

This section first reviews a selection of empirical studies on the determinants of collaboration with special attention to industry-science partnership and also reports some empirical evidence on the effects of these collaborations at the firm level. Afterwards, results of empirical studies on the

evaluation of R&D policies are briefly introduced. These two components then lead to studies that analyzed both the effects of R&D policies and collaboration on firms' innovation activity.

Empirical studies on collaboration

Recent empirical studies have established that contractual forms of R&D, such as joint R&D, have become a very important mode of inter-firm and science-firm collaboration as the number of partnerships has largely increased (Sakakibara, 1997; Hagedoorn/Narula, 1996). Several empirical papers on R&D collaborations are reviewed in Veugelers (1998). As one recent example, Cassiman and Veugelers (2002) explored the effects of knowledge flows on R&D co-operation. Their results suggest that firms with higher incoming spillovers and better appropriation have a higher probability of co-operating in R&D which confirms the arguments on spillovers made by theoretical contributions.

Not many studies analyze industry-science collaborations explicitly. Hall et al. (2003) conducted a survey-based study of research projects having universities as research partners within the U.S. ATP program. They argue that universities are involved in such projects that apply "new science", i.e. firms seek for expertise to absorb results of basic research. The role of the university may be a translation of basic science towards an applicable technology for selected problems. This interpretation is supported by the fact that universities are engaged in industry collaboration in fields where business R&D is closer to science, particularly in areas where technology tends to be more complex. University involvement also occurs more frequently in projects that are broader in scope. Projects where results are expected in a timely manner for a specific technological problem are typically not conducted in collaboration with universities.

Cassiman and Veugelers (2005) explore the determinants of industry-science collaboration using Belgian Community Innovation Survey (CIS) data. They emphasize that there are large industry differences in the probability of a firm collaborating with science. Firms in the chemical and pharmaceutical industry are most likely to collaborate with universities. Furthermore, firms that are impeded by high cost of innovation are often attracted by government subsidized cost-sharing in public-private partnerships. In addition, larger firms are more likely to collaborate with universities than smaller firms indicating that some minimum absorptive capacity is needed for fruitful collaboration. In contrast, there is no evidence for the risk-sharing argument in industry-science collaborations, which the authors relate to potentially higher transaction cost when communicating with science. Similarly, Belderbos et al. (2004a) also analyze the determinants of university collaboration, but they also account for engaging in collaboration with different types of partners in a system of equations where they include a measure of incoming spillovers from these potential collaboration partners. Among others, one interesting finding is that spillovers received from universities not only stimulate industry-science partnerships but also R&D collaboration with other partners.

Belderbos et al. (2004b) investigate the impact of R&D collaboration on firm performance using panel data of Dutch manufacturing firms. The interesting feature of this study is the distinction of two dependent variables, growth of labour productivity and of firms' productivity in innovative sales, where the latter is measured as growth rate in sales of products that were market novelties.

It turns out that R&D collaborations with competitors and suppliers positively affect productivity growth. Belderbos et al. refer to this as result of incremental innovation leading to higher sales of established products. For market success of more radical innovation projects, however, university collaborations play an important role along with the cooperation with rivals. They also find that customers and universities serve as important sources for sales growth in market novelties in absence of formal collaborative agreements.

Empirical studies on R&D policy

The impact of R&D policies on firms' innovation behaviour has been of interest in the economic literature for decades. The predominant question investigated is whether public subsidies crowd-out private investment. David et al. (2000) survey microeconomic and macroeconomic studies on that topic. One result of their survey was that most estimations in the reviewed studies are subject to a potential selection bias as recipients of subsidies might be chosen by the government because they are the most promising candidates for successful research projects. In this case, public funding becomes endogenous to innovative activity and this has to be taken into account. More recent studies correcting for selection include, among others, Busom (2000), Wallsten (2000), Lach (2002), Czarnitzki/Fier (2002) and Almus and Czarnitzki (2003), Duguet (2004), Czarnitzki and Licht (2006), Gonzalez et al. (2006) and Hussinger (2008). Results are ambiguous: Busom finds positive effects of public funding on R&D in Spanish manufacturing, but cannot rule out partial crowding out for a subsample of firms. Wallsten finds full crowding out effects in the US SBIR program, an initiative to foster innovation in small and medium-sized US companies. Lach reports large positive effects for small firms in Israel's manufacturing, but no effects for large firms. The analysis of Czarnitzki and Fier rejects full crowding-out effects in German service industries. Almus and Czarnitzki analyze Eastern German manufacturing where the government offers a high amount of subsidies in order to enhance the transformation process from a planned economy to a market economy since the German reunification in 1990. They conclude that about 50% of R&D performed in Eastern Germany would not have been carried out in the absence of public innovation programs. Similarly, Czarnitzki and Licht (2006) compare firms in Western and Eastern Germany and also extend the treatment effects estimation to a second-step where the productivity of privately financed R&D and subsidized R&D is compared. They find that subsidized R&D is almost as productive with respect to patent output as other R&D. See Hussinger (2008) for a related result on new product sales. Duguet (2004) rejects crowding-out in R&D using a sample of French firms. Gonzalez et al. (2006) employ a large panel of Spanish manufacturing firms and find no evidence for crowding-out either.[2]

Studies combining collaboration and R&D policy

Just a few empirical analyses, however, deal with R&D co-operations as a part of firms' innovative behaviour *and* as a policy instrument. Among those, Sakakibara (2001) analyzed Japanese government-sponsored R&D consortia over 13 years and found evidence that the diversity of a consortium is associated with greater R&D expenditure by participating firms. The

[2] Fewer studies deal with public policies and general firm performance, such as employment or sales growth. See the survey by Klette et al., 2000, for examples of such studies.

results support the thesis that high spill-over effects occur. The magnitude of the effect of the participation in an R&D consortium on a firm's R&D expenditures is found to be 9%, on average. Branstetter and Sakakibara (2002) examine the impact of government-sponsored research consortia on the research productivity in Japan by measuring their patenting activities over time. They find evidence that participants of research consortia tend to increase their patenting after entering a consortium, which is interpreted as evidence for spillovers above the "critical level". The marginal increase of participants' patenting in targeted technologies, relative to the control firms, is large and statistically significant.

Czarnitzki and Fier (2003) employ econometric matching analysis to investigate whether R&D collaboration leads to higher patent outcome as a measure of intermediate innovative output. Controlling for R&D input, firm size, industry heterogeneity and other common covariates, they find that firms that collaborate achieve higher patent outcome than under no collaborative agreements. Using German data they also demonstrate that German R&D policy in the 1990s increasingly subsidized research consortia comprising of firm-firm partnerships or industry-science partnerships. Consequently, they also analyze whether firms that were engaged in a publicly funded research consortium innovate more in terms of patents than firms that engaged in collaboration on a privately financed basis. Czarnitzki and Fier find that firms in publicly-sponsored research consortia indeed file more patents than other collaborators. This can have several reasons, however, which could not be further disentangled. First, the higher output of patents can be due to the monetary value of the subsidy in the sense that R&D is increased as response to the receipt. However, it can also be the case that firms in publicly funded research consortia interact to a larger extent with universities or other public research institutions as such consortia were given preferential treatment by the funding agency. This would hint at higher spillovers in industry-science relationships.

Czarnitzki et al. (2007) employ a heterogeneous treatment effects estimator where R&D collaboration, R&D subsidies and the combination of both are considered as a treatment. Their analysis is conducted for Community Innovation Survey data from Germany and Finland. Although the two countries have similar frameworks for technology policy, it can be observed that the frequency of R&D collaborations is much higher in Finland than in Germany in the early 2000s. Czarnitzki et al. (2007) find that both R&D collaboration and public R&D grants result in higher R&D in the treated firms. Firms that receive subsidies and are engaged in R&D collaboration exhibit complementarities, that is, they invest more in R&D than any other group of firms, which amounts to the estimate of three counterfactual situations of investment under "only subsidy receipt", "only collaboration" or "neither subsidy receipt nor collaboration". This also points to the presence of sufficiently large spillovers in collaborative agreements, so that firms increase R&D input. Another interesting result of their study is the analysis of "treatment effects on the untreated". As said above, the level of R&D collaboration is high in Finland. The econometric estimations have shown that firms not engaged in collaboration would not invest more in the counterfactual situation of engaging in R&D collaboration. In Germany, however, where R&D collaboration is less frequent, Czarnitzki et al. found that firms would invest more in R&D if they would engage in collaboration, on average. Thus, the authors conclude that there would be additional room for fostering collaboration in German technology policy while in Finland this seems to be limited. The Finish population of non-collaborating firms is to a larger

extent characterized by very small firms than in Germany. Such firms may not have the necessary absorptive capacity or capabilities to benefit from R&D collaborations.

Suggestions for Policy Evaluation

As of today, there is no single study that has analyzed the treatment effects of publicly subsidized collaboration with public research institutions within R&D tax credit schemes. This, however, appears to be a further step in the evaluation of current (European) policy practices. Several countries' R&D tax credit schemes include additional incentives for industry-science partnerships. For instance:

- Belgium maintains a withholding tax credit since 2005. Companies collaborating with a European university or with Belgian research institutes are entitled to keep 75% of the withholding tax the companies are supposed to pay for the researchers.

- In Denmark, companies undertaking R&D in-house are allowed a 100% deduction of R&D expenses. However, companies engaging in collaborative R&D with a university or public research institute are allowed a 150% deduction from taxable income.

- In Hungary, a 300% allowance from taxable income is granted. This incentive is offered in cases where the company maintains a laboratory at a university or public research institution.

- The Netherlands maintain an R&D wages tax credit scheme which takes the form of a reduction of the tax and social insurance contributions of the firm. It ranges from 14 % for large companies to 42% for small companies. However, the company does not need to carry out R&D in-house. As long as the R&D activities are performed on the basis of written collaborative agreement with other organizations which employ and pay wages to scientists and researchers, such as universities, the allowance is granted.

- Within the Norwegian SkatteFUNN scheme companies can deduct R&D cost of up to 5.5 million NOK. If R&D is conducted in collaboration with a university or qualifying research institution, this cap has been 8 million NOK. In 2008, it was increased to 11 million NOK for industry-science collaborations.

- In Spain, R&D expenditures on projects contracted with universities or other research organizations are given an extra tax credit of 10 per cent over the regular rate.

Given these incentives, evaluations of such schemes appear to be useful for countries considering an introduction of additional incentives for collaboration in their tax credit programs.

Evaluations of policy schemes can be conducted in various forms. Techniques range from quantitative, econometric studies, qualitative assessments to in-depth case studies of selected

companies. Econometric studies require availability of large scale databases at the firm level. If, however, such data is easily available, cross-country evaluations can be conducted at relatively low cost. Qualitative analyzes and in-depth case studies typically focus on some selected firms and can deliver more details than econometric studies. Disadvantages, however, are typically high cost of comparable cross-country studies as such evaluations may involve extensive interviews with awardees, and also the generalization of results from selected cases to the population of awardees.

As empirical evidence on R&D tax incentives for collaboration with research institutions is currently non-existent, it is recommended to conduct an econometric evaluation study as a first step. The first question that should be investigated is whether program awardees react with increased R&D to the collaborative research subsidy. This could also shed light on the existence of sufficient knowledge spillovers among collaborating parties. In a further step, innovation output measures could be taken into consideration. A quantitative analysis for this special case has the advantage that the necessary data should have been collected by the program administration to a large extent and that studies for different countries may deliver robust evidence on the policies' success. The following paragraphs recommend some possible set-ups for econometric evaluation studies.

An econometric evaluation of R&D tax credit programs typically requires panel data where subsidy recipients' variables of interest had to be observed over time. In addition, policy changes (e.g. in the allowed rate of tax deduction) had to be observed (see e.g. Hall and van Reenen, 2000). As R&D tax credits typically apply to all R&D performers in an economy, control group approaches where subsidy recipients are compared with non-recipients are not applicable. Although it is well known that not all eligible companies in fact apply for R&D tax credits, the reasons for this behavior are not generally known and this questions the validity of such firms as control observations for the purpose of comparison. Consequently, researchers typically exploit panel data including policy changes. If the policy is not subject to crowding out effects, an increase in the allowed tax reduction should coincide with an observed increase in R&D spending of tax credit recipients over time, and vice versa (see e.g. Hall et al., 2005). So far, evidence suggests that typically each dollar of tax allowance leads to a dollar change in companies' R&D roughly.

Designing econometric evaluations

The parameter of interest on most common policy evaluations is the so-called "treatment effect on the treated" (*TT*). The standard evaluation question when a subsidy scheme is evaluated compares the observed innovation activity to a counterfactual situation when the policy under review is hypothetically absent. Then, the question of interest becomes "How much would a firm that has received a subsidy have spent on R&D activities if it would not have been subsidized?":

$$\gamma_{TT} = E\left(Y^T \middle| S=1\right) - E\left(Y^C \middle| S=1\right), \qquad (1)$$

where Y^T refers to the potential outcome (e.g. R&D expenditure) of firms that receive subsidies, and Y^C to the situation where they do not. S indicates the treatment status. It is equal to 1 for treated firms and zero otherwise. Thus, the *TT* results from comparing the actual outcome of subsidized firms with their outcome in case of not receiving a grant which is not directly observable and therefore often referred to counterfactual or potential outcome.

The approach of measuring potential outcomes goes back to Roy (1951). The outcome $E\left(Y^T \middle| S=1\right)$ can be estimated by the sample mean of Y in the group of subsidized firms. In order to identify $E\left(Y^C \middle| S=1\right)$ one needs to make further assumptions. The latter cannot simply be calculated from non-subsidized firms as

$$E\left(Y^C \middle| S=1\right) \neq E\left(Y^C \middle| S=0\right) \qquad (2)$$

due to non-random assigned treatments. This would only be valid in an experimental setting where subsidies are granted randomly to firms, which is obviously not the case in current innovation policy practice.

The econometric literature offers a variety of methods for estimating $E\left(Y^C \middle| S=1\right)$. Commonly used are matching methods, parametric treatment effect models, instrumental variable techniques and (conditional) difference-in-difference estimation if panel data is available (see e.g. surveys by Heckman et al., 1999, or Imbens and Wooldridge, 2009). The applicability of these methods depends to a large extent on data availability, but all make use of control groups in one or the other form. The next section discusses a possible outline for an evaluation of R&D tax credit schemes for industry-science collaboration.

Panel data and introduction of an industry-science bonus

Suppose one is interested in the question whether the introduction of an extra tax credit for industry-science collaborations results in higher levels of R&D spending at the firm level. Consider two periods. Assume that R&D of tax credit recipients is observed in t_0 and t_1, but the bonus for industry-science collaboration is only introduced in t_1 (and assume that all firms actually engaging with universities also claim the extra tax credit). The "treated" firms are those that receive the extra bonus in t_1. An intuitive approach for estimating the counterfactual situation is based on observing R&D of these firms in t_0 in absence of the policy. Thus simply comparing R&D of the "treated" firms in t_1 and t_0 would give an indication of the treatment effect ("before-after" estimation). However, the change in R&D over time can also be influenced by macroeconomic shocks. Therefore, the change in R&D of treated firms over time can be compared to a control group of R&D performers that do not claim the new collaboration tax credit in t_1. If one is prepared to assume that macroeconomic shocks hit all tax credit recipients in similar way, this estimator would control for changes in R&D levels over time (difference-in-difference estimation).

In a standard panel data model setting, one would, in a sample of tax credit recipients, regress R&D on a dummy that is equal to one in period t_1 if the firm claimed the extra bonus for interacting with science (and zero otherwise), and other appropriate control variables (e.g. firm size and other measures commonly used in such studies) including firm-fixed effects. In such setting, one would expect a positive and significant coefficient of the industry-science dummy. In terms of an equation, it may be written as

$$R\&D_{it} = c_i + \beta x'_{it} + \gamma T_{it} + \delta t + e_{it} \qquad \text{with } i = 1,\ldots N, \text{ and } t = 0,1,$$

where c_i denotes a firm-specific intercept, x a vector of firm characteristics and T represents the treatment dummy, i.e. the fact that the firm claimed the extra industry-science collaboration tax credit, and β, γ, and δ are coefficients to be estimated. The treatment effect would be γ.

A positive sign of γ can, however, result from two different sources in the special case of evaluating the policy for industry-science collaboration. In t_0 some firms may have already collaborated with universities in absence of the extra tax credit for industry-science collaboration, and others may not have done so, but decided to start collaborating as a response to the new policy incentive. Thus, as outlined above the coefficient of the dummy variable would comprise two different effects: the pure "money" effect of the subsidy making R&D relatively cheaper compared to other factor inputs in production, and the "spillover" effect because of engaging in industry-science collaboration. In an appropriate evaluation of the policy it would be interesting to disentangle these two effects. Consequently, it would be desirable to observe the fact of "industry-science collaboration" in both periods t_0 and t_1. Then one would distinguish three groups of firms within the tax credit recipients: a) those firms that collaborated with science in t_0 and t_1 and claim the extra collaboration R&D tax credit in t_1; b) firms that did not collaborate in t_0, but did so in t_1 and claim the extra tax credit; and c) firms that did not collaborate in any of the periods and just received the standard tax credit on both periods.

Consequently the equation would change to:

$$R\&D_{it} = c_i + \beta x'_{it} + \gamma^{(a)} T_{it}^{(a)} + \gamma^{(b)} T_{it}^{(b)} + \delta t + e_{it}.$$

The estimated coefficient of the dummy variable indicating the group (a) will now reflect the pure "money" effect of the subsidy, as the status of industry-science collaboration did not change between the two periods for these firms. The estimated coefficient of the dummy variable labeling group (b) should be expected to be larger than that of group (a) as this includes both a money effect and a spillover effect. Consequently, one should subtract the coefficient of the (a) dummy from the (b) dummy in order to get an estimate for the spillover effect. The group of firms that only received the standard tax credit should be included as control group as R&D may change over time due to common macro economic shocks. This allows estimating the coefficient δ, the effect of a common macroeconomic shock from period 0 to 1, independently of the treatment dummies.

If one believes that the R&D tax credit recipients in group (c) differ substantially from those in groups (a) and (b) one may cast doubt on the assumption that the (c) firms respond similarly to a macroeconomic shock. In that case, one could only include firms of the (c) group that are similar in their characteristics x in t_0, that is, one would "match" the firms in (a) and (b) to firms in (c) conditional on x. This would amount to the so-called "conditional difference-in-difference" estimator.

In practice, the impact of the spillover effect on R&D investment may only materialize after some time of interacting with the university. Thus it would be desirable to consider not only two periods but allow for at least one further year of industry-science interaction before an evaluation is conducted.

In this example, I only refer to the R&D investment of the firm as variable of interest. However, evaluations could be extended to output measures such as patenting or sales with market novelties to investigate the nature of R&D conducted in firms collaborating with universities as response to preferential tax treatment. In similar spirit as the study of Belderbos et al. (2004b), one may hypothesize that university collaboration may lead to a change in the type of R&D conducted by the firm. R&D may become more basic or "radical" which may be reflected in more cutting-edge innovations that the firm introduces.

An alternative approach for estimating counterfactual situations in the context of innovation policy has recently been introduced by Takalo et al. (2009). They build a structural model that allows estimating R&D outcome under different policy regimes. In their paper they compare R&D in Finland under the current system of R&D grants with the hypothetical situation where the budget spent on R&D grants would distributed via R&D tax credits. In principle, this model could also be applied to the special case of extra incentives for industry-science collaborations within R&D tax credit schemes, but it is much more demanding in terms of data requirements and efforts in terms of empirical implementation.

Discussion

This paper discussed some economic aspects of the current policy practice of granting extra tax incentives to firms that engage in industry-science collaborations within R&D tax credit schemes of some EU member states.

As outlined, theories of industrial organization suggest that R&D collaborations may lead to higher R&D because firms can internalize potential external effects of R&D, that is, free-riding of other firms due to knowledge spillovers. Furthermore, it has been described that collaborations with universities or other public research institutions may lead to higher R&D than collaborations with horizontally related firms as the former do not exert a negative externality on profitability since universities are not involved in any market rivalry with the firm.

In addition to the potential knowledge spillover effect, business R&D may be influenced by subsidies. Granting extra R&D tax credits for industry-science collaboration is currently practiced in several EU member states. Thus, firms may benefit in two ways from the collaboration with science. First, they may benefit from knowledge spillovers and second, the extra tax incentives lower the price of R&D conducted in the firm.

As an outline for potential evaluations of these policies in European member states, I suggest an econometric analysis (difference-in-difference estimation) that allows estimating "treatment effects" of such policies. As an example, it is proposed to investigate the level of R&D investment in recipient firms, or more specifically, how R&D investment changes as a response to such policy. This is an especially interesting case, as the policy comprises two "treatment components". First, the extra tax incentive exerts a pure "monetary" benefit on the firm, as R&D becomes relatively cheaper when compared to other factor inputs. Second, the policy may induce firms to engage more in industry-science collaborations. If so, there may be a separate "spillover" effect that results in increased R&D investments at the firm level, in addition to the monetary effect of the subsidy.

However, industry-science collaborations may not be unambiguously welfare-enhancing. If it is believed that the primary task of university research is basic science and that results of basic science lead to higher welfare in the long run, one may ask whether basic research suffers from industry-science collaboration to some extent. Increased commercialization of university research may distract researchers from their basic research tasks. This assumption is not implausible as a firm typically seeks specific solutions for technological problems emerging in its business. Thus, engaging in industry-science collaborations may force university researchers to shift their attention to more applied research questions that possibly have to be addressed within tight deadlines. Basic research output might suffer under these circumstances. Czarnitzki et al. (2009) analyze this question using individual data of German professors. They correlate their publication counts and quality with patenting activity where patents are differentiated into purely academic patents and corporate patents. The latter are patents where the university researcher appears as the inventor and a firm as the patent applicant. This can be interpreted as an indicator for an engagement in industry-science collaboration. Regression analysis shows that such collaboration harms the publication output of the scientist with respect to both quantity and quality whereas commercialization activity measured as academic patenting does not. Lower (quality) publication output may be an indication of the opportunity cost of science-to-industry technology-transfer policies, especially if additional R&D tax incentives for industry-science collaborations are financed by reductions in basic public university budgets. The potential benefits to business R&D should therefore be carefully assessed against potentially negative effects occurring in knowledge output of public science.

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