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The effects of cooperative R&D subsidies and subsidized cooperation on employment growth

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Abstract

The paper investigates the contribution of cooperative and non-cooperative R&D subsidies to firm growth. Of particular interest is hereby firms' embeddedness into subsidized cooperation networks. For the empirical analysis we utilize an unbalanced panel of 2.199 German manufacturing firms covering the time period from 1999 to 2009. A dynamic panel estimation technique is employed to control for growth autocorrelation as well as endogeneity.
Our findings show that non-cooperative R&D subsidies have a stimulating impact on large firms' employment growth. In contrast being engaged in many subsidized cooperation is related to significant growth-reducing effects. In the case of large firms, exceptions are subsidized cooperation with geographically distant firms, which can positively influence employment growth. For small firms, rather interactions with research organizations are found to facilitate their development.

Keywords R&D subsidies, cooperation network, firm growth, serial correlation
JEL Codes H25, J23, D85

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1 Introduction

Firm growth and its determining factors have received considerable attention in the literature (see for a review Coad, 2009). Amongst these factors are R&D (research and development) subsidies, which are argued to support innovation activities and thereby (indirectly) facilitate their economic development (Busom, 2000). Rich empirical evidence exists that confirms such positive effects of R&D subsidies (cf. Czarnitzki et al., 2007).

The adaption of knowledge from firm external sources is another growth stimulating factor that is particularly emphasized in endogenous growth theories (Romer, 1990). The absorption and utilization of such knowledge is achieved via various mechanisms including firms' engagement in inter-organizational cooperation. The contribution of cooperation to firm' economic performance has also been subject to many theoretical and empirical studies (cf. Powell et al., 1996; Powell et al., 1999). In this literature it is widely accepted that firms' generally benefit from cooperating with other organizations.

While significant empirical evidence exist for cooperation and R&D subsidies facilitating firms' development (cf. Brouwer et al., 1993; Czarnitzki et al., 2007), it is rarely considered that firms frequently (and to an increasing extent) engage into inter-organizational cooperation in order for being rewarded with R&D subsidies. By participating in such programs firms become embedded into (subsidized) cooperation networks (Broekel and Graf, 2011), which can have significant effects on firms' innovation and patenting activities as Fornahl et al. (2011) recently highlighted in their study on the German biotech industry.

The present paper contributes to these literature streams with an empirical study on the relevance of non-cooperative and cooperative R&D subsidies for firms' employment growth. We are evaluating their relative importance and, in case of cooperative subsidies, also explicitly take into account their function of embedding firms into (subsidized) cooperation networks. More precise, we particularly investigate the impact of a firms' position in these networks and whether it matters with what types of organizations they cooperate with.

Our study is based on a panel of 2,199 German manufacturing firms covering the time period from 2004 to 2009. A Systems-GMM approach is applied to deal with endogeneity and growth autocorrelation.

The empirical analysis provides empirical evidence for non-cooperative R&D subsidies positively influencing the employment growth of large firms. This contrasts the results for cooperative R&D subsidies for which no direct effects are identified. It matters however that firms engage in subsidized cooperation. For instance, we find a growth-stimulating effect of cooperating with public research organizations. In case of large firms rather interacting with geographically distant firms seem to be of larger importance. We also observe negative effects being associated to cooperating, which are primarily related to extensive participation in subsidized cooperation.

The structure of the paper is as follows. Section 2 reviews the literature on the empirical evaluation of subsidies and cooperation as well as their relevance for firm growth. Hypotheses are subsequently developed in the same section. Section 3 focuses on the methodology, the employed data, and the construction of the empirical variables. The findings are presented and discussed in Section 4. Section 5 concludes the paper.

2 Theoretical background and hypotheses

A substantial literature studies the determinants of firm growth. McKelvie and Wiklund (2010) summarize the main research streams within this literature. The first of these streams focuses on growth as the outcome of economic processes and firm characteristics. The second stream concentrates on the results and effects of firm growth and the third stream studies the growth process itself. The present paper fits into the first stream by focusing on the role subsidies play for the economic success of firms.

Subsidies and the evaluation of their impact on the economic success of firms have received substantial empirical attention in the literature. It has, for example, been shown that subsidies impact firms' R&D efforts (cf. Busom, 2000; Gorg and Strobl, 2007) and employment growth (cf. Brouwer et al., 1993; Girma et al., 2008). In other words, subsidies are shown to be very relevant for firms' economic development.

In the following, we focus on one particular type of subsidies, namely R&D subsidies. There are multiple reasons for R&D subsidies being granted. For instance, they are used to stimulate private research in fields that are politically desirable. In Germany this applies to new technologies and so-called key technologies that are foremost supported (Fier, 2002). Subsidies for R&D are also argued to be necessary because private investments into R&D activities are perceived to be below a social optimum. The uncertainty and risks involved in innovation activities are particularly important amongst the reasons for insufficient investments (Cantwell, 1999). Financial constraints further reduce the amounts invested in R&D and strongly hamper innovation. R&D subsidies can remove these obstacles by providing additional financial resources for innovation-oriented activities. As for subsidies in general, the financial aspects of R&D subsidies have therefore received most attention in their scientific evaluation (cf. Czarnitzki and Hussinger, 2004; Czarnitzki et al., 2007).

The empirical relation between R&D subsidies and employment growth is likely to be different from that between employment growth and other types of subsidies. First of all, R&D subsidies are predominantly aimed at expanding firms' R&D capacities and impact their ability to grow in the middle and long run. Their effects on employment are thereby indirect in nature contrasting the rather direct effects of many other subsidies types.

Secondly, R&D subsidies generally tend to be relative small in terms of granted monetary amounts. For the empirical investigation it implies that the empirical detection of an impact on employment growth is less likely.

Thirdly, firms participating in R&D subsidy programs are probably structurally different from those that apply for non-R&D related subsidies. Foremost, the latter firms do not necessarily conduct R&D, which is however a requirement for firms' to obtain R&D subsidies. This may impact the empirical findings insofar as firms active in R&D show different (more positive) growth patterns than those that do not invest in R&D (Brower et al., 1993).

Despite these unique characteristics of R&D subsidies they are expected to stimulate firms' employment growth, which is supported by already existing empirical evidence (Czarnitzki et al., 2007). Our first hypothesis emphasizes these potentially positive effects of R&D subsidies.

H1: R&D subsidies facilitate firms' employment growth.

Another growth-stimulating factor that has received considerable attention in the recent literature is a firm's capability to invent and use new knowledge (Zahra et. al., 2006). Cohen and Levinthal (1990) famously pointed out that a firms' competence in absorbing external information and knowledge is crucial in this respect (absorptive capacity). O'Regon et.al (2006) argue similarly that firms are unlikely to sustain their competitive advantage without access to greater (and potentially external) research and development resources. It is therefore particularly important for firms to interact with external knowledge sources to continuously innovate and generate growth momentum (cf. Powell et al., 1996).

One way for firms to access external knowledge is to engage in formal and informal cooperation with other organizations.[1] Such inter-organizational cooperation in R&D is an important supplement to internal R&D activities as it generally increases the probability of innovative success (Oerleman and Meeus, 2000). Cooperating organizations benefit from the sharing of risks and costs (Cassiman and Veugelers, 2002), access to complementary knowledge and assets (Teece, 1986), and their transfer into the organization (Eisenhardt and Schoonhoven, 1996). Accordingly, it can be argued (and it is empirically shown) that firms, which are well embedded into a wide range of cooperation are likely to be in superior positions for achieving above average innovation performance and eventually employment growth (cf. Powell et al., 1996).

However, cooperation might not always be beneficial. The establishment and maintenance of cooperation agreements require efforts. Cooperation might fail, which implies a wasting of these efforts (Bleeke and Ernst, 1993). Another reason for potential negative effects of cooperation is free-riding on partners' R&D efforts (Kesteloot and Veugelers, 1995). "[L]earning races between the partners [...], diverging opinions on intended benefits [...] and a lack of flexibility and adaptability" (Faems et al., 2005, p. 240) can additionally induce negative effects. Another danger inherent to cooperative activities is the potential "leakage" of crucial knowledge to competitors (De Bondt et al., 1992).[2]

Nevertheless, cooperation is generally perceived to enhance firms' economic performance (cf. Li and Vanhaverbeke, 2009). This has also been noticed by policy. An increasing number of programs aiming at the stimulation of growth are characterized by strong cooperative elements. In addition to the previous arguments, policy intervention is motivated by the fact that some projects are too big to be realized by a single organization, which makes cooperation a necessity. Policy also frequently tries to stimulate technology transfer from public to private organizations. Universities and research organizations are encouraged to participate in the respective funding programs and to engage in cooperation with private firms. Prominent examples for such policies are the framework programs by the EU, which provide strong incentives for firms and research organizations to engage in joint projects (cf. Scherngell and Barber, 2011).

In a similar fashion, the German federal government is increasingly supporting cooperative (i.e. joint) projects with R&D subsidies. Broekel and Graf (2011) estimate that

[1] Other mechanisms are for instance labor mobility and the exchange of embodied knowledge via the trading of good and tools.

[2] See also Broekel et al. (2011) for a discussion of these issues.

about 30% of all R&D subsidy grants by the German federal government are given to consortia of organizations realizing joint research projects. These authors as well as Fornahl et al. (2011) argue that such cooperative subsidies might take effect on firms' performance beyond the "simple" monetary effects because they also imply active engagements in cooperative activities. In contrast to unsubsidized cooperation, which are frequently approximated by patents (Ejermo and Karlsson, 2006), venture capital syndication (Sorenson and Stuart, 2001), director inter-locks (Mizruchi, 1996), joint publication (Ponds et al., 2010), or interview data on inter-organizational interaction (Uzzi, 1996), little is known about the relationship between such subsidized cooperation and firm performance. While most of the literature agrees that (unsubsidized) cooperation generally enhances innovative and economic performance it is still unclear whether the same can be said about subsidized cooperation.

Differences in the structure and effects of subsidized and unsubsidized cooperation can be expected to exist, though, because policy heavily interferes in the establishment and process of (subsidized) cooperation. For instance, it defines the general conditions of cooperating in subsidies programs and selects those proposals that are granted, which might not be the ones that are economically most beneficial. Moreover, the pool of potential cooperation partners is likely to differ between unsubsidized and subsidized cooperation as in the latter case it will include only those organizations that (for whatever reasons) seek and apply for R&D subsidies.

Despite these differences to unsubsidized cooperation, subsidized cooperation is also shown to impact firms' economic success. Fornahl et al. (2011) provide empirical evidence for the existence of differences in the effects of cooperative and non-cooperative subsidies for the German biotech industry. These authors show that a firm's innovation performance is not enhanced by non-cooperative subsidies but by firms being engaged in subsidized cooperation. This motivates our second hypothesis.

> *H2: Cooperative R&D subsidies are more conducive for employment growth than non-cooperative R&D subsidies.*

Broekel and Graf (2011) as well as Fornahl et al. (2011) argue further that by participating in joint projects, organizations become embedded into inter-organizational cooperation networks. These cooperation networks are likely to represent effective channels of knowledge diffusion, i.e. knowledge networks, because participating organizations agree to substantial knowledge sharing regulations. Accordingly, knowledge network effects might also be present when firms engage in subsidized joint projects. Such effects imply that knowledge can diffuse beyond directly linked organizations. It means further that a partner's partners become relevant for a cooperating firm. Fornahl et al. (2011) find that firms' with many direct links do not experience above average innovation performance. Rather those firms benefit from being embedded in subsidized cooperation networks that have easy access to knowledge located at very different areas in the networks. On this basis we formulate the third hypothesis as follows.

> *H3: Firms profit from holding central network positions with easy access to knowledge located elsewhere in the network.*

Partnering organizations need to “fit” to each other in order to profit from cooperating. This involves a common understanding of the joint project‘s aims and the willingness to share knowledge, resources, as well as capabilities (cf. Cantner and Meder, 2007). Moreover, different forms of proximity between the partners (geographic, institutional, social, organizational, and cognitive) impact the effectiveness of interacting (Boschma, 2005). As in the case of unsubsidized cooperation, it matters with whom organizations cooperate. The empirical literature suggests that linkages to research organizations and universities might be especially knowledge rich and valuable (cf. Beise and Stahl, 1999; Raspe and van Oort, 2011). The fourth hypothesis takes these findings up.

H4: Subsidized linkages to research organizations and universities enable firms to outgrow firms that primarily cooperate with other firms.

Another aspect that has frequently been investigated is the relevance of the geographical dimension of firms’ cooperative links. Geographic proximity to partners is frequently argued to enhance the effectiveness of inter-organizational knowledge exchange (see for a discussion Boschma, 2005). Accordingly, organizations that frequently cooperate with organizations located within small geographic distance are more likely to benefit from cooperating (Oerlemans and Meeus, 2005). Our fifth hypothesis highlights such effects of geographic proximity.

H5: Geographic proximity to cooperation partners enhances the effectiveness of knowledge transfer and thereby is conducive for firm growth.

So far, we treated all firms as being homogenous. However, there are good reasons to believe that some of the previously outlined relationships vary in their importance for different types of firms. For instance, research on SMEs reveals that these firms especially obtain a great share of knowledge from external advisors, universities, and other firms (cf. Beise and Stahl, 1999; O’Regan et.al. 2005; Raspe and van Oort 2008). Accordingly, we expect cooperation and in particular cooperation with research organizations (including universities) to be more important for small than for larger firms. This leads to the sixth hypothesis, which highlights these differences related to firm size.

H6: Differences exist in the importance of subsidized cooperation between small and large firms. Links to research institutes and universities are particularly more conducive to small firms’ growth.

In the following, we present the employed database before the approach is discussed with which the six hypotheses are empirically tested.

3 Data source and empirical variables

3.1 Data sources

We use the MARKUS database provided by the Bureau van Dijk as data source. It contains 1.3 million German, Austrian, and Luxembourgian firms. For this paper we focus only on German manufacturing companies with information on their names, industry affiliation, zip code, sales/turnover, and their total employment numbers. Sales/turnover and employment data are available for the time period from 2001 to 2010, however with many missing values. In an initial step, a firm population is selected consisting of 14,018 firms for which sales/turnover and employment information is available at least for the time period 2004 to 2009.

This information is matched to data on R&D projects that were subsidized by the following German federal ministries: Ministry of Education and Research (BMBF), Ministry of Economics and Technology (BMWi), and the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU). Accordingly, the data covers the most important sources of R&D subsidies on the federal level. It is recorded in the so-called "Förderkatalog" (subsidies catalogue), which is accessible via the website www.foerderkatalog.de. The database offers very detailed information on more than 110,000 projects that were supported between 1960 and 2009 including information on the name and location of the receiving organization. It is important to point out that the data does not provide complete information on all types of R&D subsidies a firm can potentially receive. Only R&D related subsidies granted by the German federal government are covered leaving aside all non-R&D related subsidies and all subsidies from other political levels (e.g. the German federal states ("Länder"), districts, and EU).

The R&D subsidies data allows for differentiating between subsidies granted to joined projects (i.e. cooperative subsidies) and those that are granted to single organizations (i.e. non-cooperative projects). Organizations that participate in such joint projects agree to a number of regulations that guarantee significant knowledge exchange between the partners. Accordingly, two organizations are defined to cooperate if they participate in the same joint project (see for more details Broekel and Graf, 2011).

Of the 14,018 firms in the sample from the MARKUS database 733 firms are identified to have received subsidies in at least one year between 2001 and 2008.[3] With just 733 of 13,285 being subsidized any subsidies based variable will be heavily inflated with zero values, which might be problematic in the empirical assessment. We therefore create a smaller control group of unsubsidized firms. More precisely, we first consider all firms that did not receive subsidies between 2001 and 2008, for which we have complete information concerning their industry classification, employment (2004-2009), and turnover (2004-2009). Second, for each of the 733 subsidized firms we chose two unsubsidized firms from this sample that belong to the same 6-digit NACE industry and that are most similar in terms of their employment number. Each of these "control" firms is considered only once. In the rare instance that a 6-digit NACE industry is too small to offer a sufficiently large number of

[3] In the empirical estimation we consider a time lag between employment growth and subsidies. The smallest considered lag is one year.

control firms, we consider firms of the same 5-digit and 4-digit industry, respectively. Accordingly, subsidized firms represent one third of the final sample, which amounts to 2.199 firms.

3.2 Descriptive statistics and correlations

The final unbalanced panel consists of 2.199 firms and 24.189 observations. Figure 1 shows the firm size distribution in 2008. Given the way the sample is constructed it closely resamples the size distribution of the 733 firms that received subsidies.

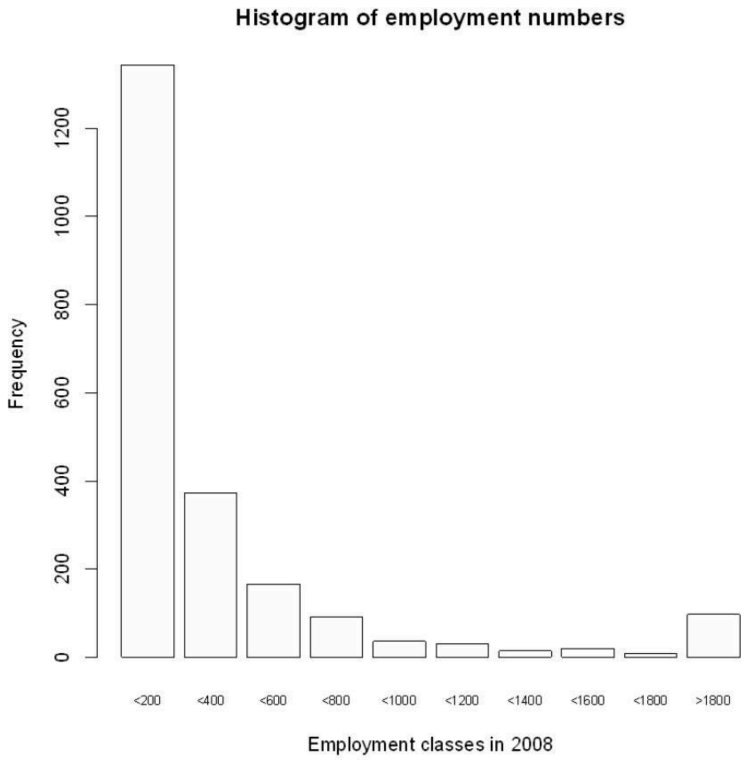

Figure 1: Distribution of employment

The figure shows that firms with less than 200 employees dominate our data base. However, compared to the overall distribution of firm sizes in Germany, the larger firms with more than 200 employees, which account for less than 1% of all German firms, are overrepresented in our sample. This reflects the overall bias of the MARKUS database towards larger firms and is further increased by the better data availability for larger firms and by larger firms being more likely to receive subsidies.

In addition to the two main characteristics of firms (employment, turnover), we construct a number of variables on the basis of the subsidies data. They are presented in the following.

The first variable of interest is the total amount of yearly R&D subsidies a firm receives from the German federal government (SUBS). For the estimation of the yearly monetary amounts we take into account each project's exact starting and ending data and distributed the total sum uniformly in time. Figure 2 pictures the distribution of granted subsidies across firm size classes. This means, for instance, that firms with less than 200 employees receive about 26 percent of the total amount of granted subsidies. Firms with more than 1,800 employees obtain the largest share of subsidies with more than 50 percent.

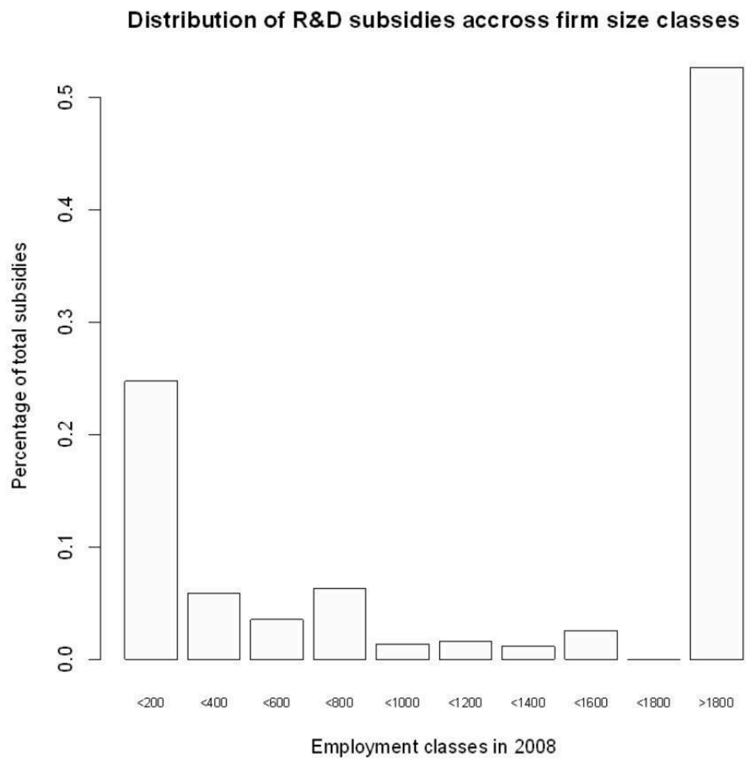

Figure 2: Distribution of subsidies across firm size classes

To get more insights into the impact of subsidies, we split the variable SUBS into the number of granted projects (PROJ) and the average amount of subsidies per project (SUBSP). This allows for assessing whether the effects of subsidies are related to the size of projects (SUPS) or to the total number of projects a firm is involved (PROJ).

The amount of subsidies is alternatively divided into the amounts coming from a firm's participation in joint projects, i.e. cooperative R&D subsidies (CSUM), and the non-cooperative R&D subsidies (SUM) that are acquired as subsidies granted to the individual firm. In a similar manner as for SUBS both numbers are also split into the average amount of subsidies per joint project (CSUMP), the number of joint projects (CPROJ), the amount of subsidies per non-cooperative project (SUMP), and the number of non-cooperative subsidized projects (SPROJ).

Using the information on firms' participation in joint projects we can draw the complete inter-organizational networks of subsidized cooperation in Germany. For these networks we consider ALL organizations (firms, universities, associations) that receive subsidies from the respective German federal ministries in a particular year. Moreover, all subsidized research organizations; universities, associations, and other sorts of organizations are included in the network (see for more details Broekel and Graf, 2011). Some network descriptive can be found in Table 1. Interestingly, the number of organizations in the network (including isolates) increases until 2002 before it declines in the subsequent years. We can only speculate about this finding, which might be a result of changes in the support policies or the burst of the ".com bubble" in 2001. By and large, the density of the network remains stable since the number of links ("edges") drops simultaneously, though.

Network characteristic	Year 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Density	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Nodes	4.069	4.333	4.807	5.263	4.972	4.541	4.414	4.414	3.949	3.331
Edges	11.309	12.161	14.539	15.159	14.118	12.274	12.047	12.571	10.170	7.543

Table 1: Network characteristics

In a common fashion, we approximate potential effects caused by firms' embeddedness into these networks through a firm's degree (DEGREE) and betweenness centrality (BETWEEN) (cf. Boschma and ter Wal, 2007). Degree centralization is straightforwardly defined as the number of links an organization has to other organizations. Or in the context of this paper, the number of unique partners a firm is cooperating with in joint projects in a particular year.

Betweenness centrality is a more complex measure. It measures if a firm holds a 'brokerage' position in a network implying that it captures the extent to which shortest paths linking other organizations 'run' through this firm (Wasserman and Faust, 1994). Firm *i*'s betweenness centrality is estimated by:

$$BETW_i = \sum_{j<k} g_{jk}(n_i) / g_{jk} \qquad (2)$$

with g_{ik} being the geodesic distance (DISTANCE) between organization *j* and *k* that are part of the network.

The following variables provide information on the composition of firms' ego-networks (their direct partners) with respect to the organizational and institutional background of their partners. We consider the share of universities in a firm's partnering organizations (UNI), the share of research organizations (RESEARCH)[4], and the share of firms (FIRMS). The remaining share of miscellaneous organizations (associations, local authorities, and other governmental entities) is not considered to avoid perfect collinearity.

As pointed out above, we are also interested in the geographical reach of a firm's ego network. For this reason we estimate the average geographic distance to all its partnering organizations, which can be seen as a measure of a firms' embeddedness into local knowledge networks (Broekel and Boschma, 2011).

The descriptive statistics of all variables are presented in Table 2. Table A1 (in the appendix) presents the correlation structure of the variables. Some interesting observations can be made in the correlation table. Most subsidies variables are notably highly correlated. For instance, the numbers of projects (PROJ, CPROJ, SPROJ) are always (and not surprisingly) correlated to the absolute monetary amounts (SUBS, SUM, CSUM). More interestingly, the numbers of cooperative projects (CPROJ) and non-cooperative projects (SPROJ) are also highly correlated with r=0.778***. Accordingly, firms that receive subsidies apply for cooperative as well as non-cooperative subsidies. However, this correlation is likely being impacted by the size of organizations, which is not taken into account in this simple

[4] This particularly regards institutes belonging to the "big four" research organizations in Germany: the Max-Planck Society, the Fraunhofer Society, the Helmholtz Association, and the Leibniz Association.

bivariate analysis. Another observation regards the two network centrality measures (DEGREE and BETWEEN), which are highly correlated with each other and with the number of cooperative projects (CPROJ). This has to be considered in the later empirical analysis.

Variable	Description	Mean	S.D.	Min	Max
EMP	Number of employees	920.83	11.618.38	1	439.000
PROD	Labour productivity (turnover in thousand EURO per employee)	305.91	3.874.21	5.92	249.000
SUBS	Amount of received subsidies	36.140.22	428.000.00	0	25.300.000
SUBSP	Amount of subsidies per project	12.855.80	47.101.84	0	1.060.000
PROJ	Number of granted projects	0.32	2.13	0	96
SUM	Subsidies granted to individual firm (non-cooperative R&D subs)	14.422.07	191.000.00	0	10.500.000
CSUM	Firm's participation in joint projects (cooperative R&D subsidies)	21.718.16	260.000.00	0	15.500.000
SUMP	Amount of subsidies per non-cooperative project	6.651.35	40.930.78	0	1.060.000
CSUMP	Average amount of subsidies per joint project	8.633.66	35.829.08	0	779.000
SPROJ	Number of non-cooperative subsidized projects	0.10	0.63	0	24
CPROJ	Number of joint granted projects	0.22	1.60	0	74
DEGREE	Number of links an organization has to other organizations	1.31	10.64	0	551
BETW	Measures if a firm holds a central position in this network	192.25	3.989.49	0	227.000
UNI	Share of universities in a firm's partnering organizations	0.02	0.10	0	1
RESEARCH	Share of research organizations	0.02	0.08	0	1
FIRM	Share of firms	0.08	0.23	0	1
DIST	Geodesic distance between organization and network	35.62	106.61	0	844

Table 2: Descriptive statistics of variables

4 Empirical approach

For the investigation of the relationship between subsidies and employment growth we follow the approach (and notation) by Girma et al. (2008). These authors specify a dynamic labour demand function that has been put forward by Nickell (1987):

$$\log(EMPL_{i,t}) = \alpha + \beta_1 \log(EMPL_{i,t-1}) + \beta_2 \log(TURN_{i,t}) + \beta_3 \log(WAGE_{i,t}) + \beta_4 \log(SUBS)_{i,t} + \tau_t + \eta_i + \varepsilon_{i,t}$$

whereby $EMPL_{i,t}$ represents the employment, $TURN_{i,t}$ the output (in terms of turnover), $\mathrm{WAGE}_{i,t}$ the average wage, and $\mathrm{SUBS}_{i,t}$ the amount of received subsidies of firm *i* in *t*. In contrast to Girma et al. (2008), we unfortunately don't have information on the wage per head and moreover find turnover to be highly correlated with employment (r=0.91***).[5] For this reason we rather use the turnover per employee, i.e. labour productivity (*PROD*), which on the one hand allows distinguishing between highly productive and less productive firms and on the other should be highly correlated to the wage per head. As Girma et al. (2008) we take the logarithm of employment and labour productivity, which yields more robust results. The subsidies variables are not logged as they involve many zero values that prevent a proper application of the log-transformation.

[5] "***" indicates a significance level of 0.01, "**" significance at 0.05, and "*" significance at 0.01.

Another difference between Girma et al. (2008) and our study is the more differentiated view on subsidies, which are considered as variable *g* in the above equation. We specify a multitude of variables approximating the extent to which firms receive non-cooperative and cooperative subsidies as well as a wide range of variables capturing their embeddedness into the subsidized cooperation networks. The adapted dynamic labour demand function looks the following:

$$\log(EMPL_{i,t}) = \alpha + \beta_1 \log(EMPL_{i,t-1}) + \beta_2 \log(PROD_{i,t}) + B * SUBS_{i,t} + \tau_t + \eta_i + \varepsilon_{i,t}$$

In contrast to the above, PROD represents the labour productivity measure and SUBS the matrix of variables based on the subsidies data.

τ_t represents time specific effects, η_i time invariant firm level ("fixed") effects, and $\varepsilon_{i,t}$ finally stands for the error term summarizing all other (stochastic) effects in both models. As common in this type of research, we consider a lagged version of the dependent variable in the estimation because of the dynamic nature of labour demand that is caused by a "non-smooth adjustment process" in firms' employment policy (Girma et al., 2008, p. 1187). The consideration of the lagged version of the dependent variable as independent variables requires the use of dynamic panel analysis (Arrelano and Bond, 1991).

In addition, when investigating the impact of subsidies on employment growth the most challenging issue is how to deal with potential endogeneity between the empirical variables. Endogeneity may be introduced to the econometric model primarily for two reasons. First, there might be certain unobserved firm characteristics impacting the probability with which firms receive subsidies and which simultaneously influence their employment growth. Such factors might be either unobservable or at least empirically hard to approximate. Second, while subsidies may influence employment growth the opposite can be the case as well. For instance, there might be policy programs specifically aiming at supporting declining or fast growing firms. For firms in declining markets it might also be a highly beneficial strategy to lobby and apply for subsidies. Accordingly, the relationship between subsidies and employment growth is not necessarily mono-directional violating a fundamental assumption of standard empirical models.

In a similar fashion as Girma et al. (2008), we overcome these issues by using the Systems-GMM estimator developed by Blundell and Bond (1998). This estimator is widely used in current literature and therefore we refrain from introducing it at great length.[6] For instance, Lachenmaier and Rottmann (2011) make use of it to investigate the effects of innovation on employment.

The idea behind the Systems-GMM estimator is that potentially endogenous variables are instrumented with their own lags. More precisely, the lags of their first difference as well as the lags of their values are used for the instrumentation. A crucial issue is hereby the validity of the lagged variables as instruments, which is related to the question of whether they can be considered to be exogenous and whether they conflict with over-identification restrictions. In a usual manner these issues are checked with a Sargan / Hansen statistic. In addition, the errors are required to be free of second-order autocorrelation, which is assessed

[6] Roodman (2009) provides an excellent introduction to this topic.

with the Arrelano - Bond test (Arrelano and Bond, 1991). The final model that is employed for the empirical analysis is a two-step Systems-GMM in the spirit of Arrelano and Bover (1995) with Windmeijer-corrected cluster robust-errors (Windmeijer, 2005).[7]

As pointed out above, R&D subsidies are unlikely to result in immediate employment expansion. However, it also seems to be impossible to define a reliable time lag between granting and the effect on employment, which is particularly the case for network effects. We therefore follow Girma et al. (2008) and simultaneously include a range of lags (1, 2, and 3 years) in the empirical analysis.

5 Empirical results

5.1 R&D subsidies and employment growth

The regression results for various models are reported in Tables A.2, A2a and A2b (in the appendix). We specify the lagged employment ($EMPL_{t-1}$), labour productivity ($PROD_t$), and the subsidies variables to be potentially endogenous. Only the included year dummies (2004 to 2008 with 2009 being the reference) are considered to be purely exogenous. In all models the lagged dependent variable ($EMPL_{t-1}$) is instrumented with the sixths lag of its level and first difference. The level and first difference of the third and fifth lag proved to provide robust results for labour productivity ($PROD_t$). With the exception of **Model 1** all subsidies based variables are instrumented with the sixth lag of their levels and first differences. In the first model, also the fifths lag of SUBS's level and difference are considered. The requirements of no overidentification restrictions (as tested with the Sargan and Hansen statistics) and exogeneity of the instruments (evaluated with a difference-in-Hansen test) are fulfilled in all models. In all but two models, further requirements of significant first-order autocorrelation and insignificant second order-autocorrelation (as indicated by the Arellano-Bond test) are met by considering the first lag of the dependent variable ($EMPL_{t-1}$). In one models (**model 8**) the second lag of the dependent variable needs to be included as well. This will later be discussed in more detail.

The lagged employment level turns out to be significantly positive and close to one in all models, which is in line with comparable findings in the literature (e.g., Bottazzi and Secchi, 2003; Coad, 2009; Girma et al., 2008). Labour productivity is found to be positively associated to employment growth (PROD). It means that highly productive firms outgrow less productive firms. The variable PROD loses its significance when including variables that account for the type of organizations firms' cooperate with (see **Models 7** and **8**). This observation suggests that a significant portion of this effect is related to highly productive firms cooperating with different types of organizations than less productive firms.

The year dummies remain insignificant with few exceptions (y2004, y2005, and y2007 in Models **7** and **8**. In all cases they obtain negative coefficients suggesting that firms' employment was lower in most years before 2009 (reference year). In other words, firms' generally increased their size in the considered time period.

In the first model we test **hypothesis 1** "*R&D subsidies stimulate the employment growth of firms"*. The significant negative coefficient of (the second lag of) SUBS clearly

[7] See Roodman (2009) for a detailed discussion of these specifications.

rejects this hypothesis and rather indicates that R&D subsidies show a negative relation with employment growth. Moreover, this finding contrasts previous results in the literature showing that non-R&D related subsidies induce higher employment growth (Girma et al. 2008). Accordingly, there are significant differences in the effects of the two types of subsidies.

The second model gives a clearer picture on the source of the negative effects. While the variables SUBSP (amount of subsidies per supported project) remains insignificant PROJ (number of projects) gains negative significance in the third lag. It implies that firms experience lower employment growth when they engage in a large number of subsidized projects. In contrast, the size of the individual project (as approximated by the amount of received subsidies per project) is not relevant for growth.

A major contribution of the present paper to the literature is the differentiated view on cooperative and non-cooperative subsidies. According to **hypothesis 2** the first ones are more likely to generate positive employment effects. The splitting of SUBS into SUMP (amount of non-cooperative subsidies) and CSUM (amount of cooperative subsidies) does not yield any significant coefficients (Model 3), though. We further differentiate between the numbers of subsidized projects (cooperative and non-cooperative) and the respective amounts of subsidies per project in **Model 4**. In this case the number of subsidized cooperative projects (CPROJ) gains significance in the first lag with a negative coefficient. In contrast, the other variables - number of non-cooperative subsidies (SPROJ), amount of cooperative subsidies per project (CSUMP), and amount of non-cooperative subsidies per project (SUMP) – remain insignificant. The high correlation between CPROJ and the total number of subsidized projects (PROJ) of r=0.982*** implies that the previously observed negative coefficient of PROJ has its cause in the negative impact of CPROJ. Accordingly, it is not the extensive engagement in subsidized projects in general that yields negative effects but rather the engagement in many subsidized cooperative projects. In light of this we have to reject hypothesis 2, which suggested a positive relationship between cooperative subsidies and employment growth. Before the implications are discussed in more detail it is worthwhile to take **Models 5** and **6** into consideration as well. They deal with **hypothesis 3** according to which firms that are central in the cooperation network should experience additional employment growth. When considering the two network measures, degree and betweenness centrality (DEGREE and BETWEEN) CPROJ loses its significance with these two variables also being insignificant. Each of the three variables is however negative significant when being separately considered, which suggests that they all explain the same effect. This is also visible in the high correlation (r>0.9***) among the three variables, see Table A.1 in the Appendix. It means that firms engaging in many cooperative projects are also very central in the cooperation network. We estimated a number of alternative models but failed to disentangle the effects of these three variables. Nevertheless, the negative relation between the number of cooperative projects (or degree and betweenness centrality) implies that we have to reject **hypothesis 3** as well, as we don't find positive effects caused by a strong embeddedness of firms in the subsidized cooperation network.

The rejection of the two **hypotheses 2** and **3** is surprising as the theoretical arguments as well as empirical evidence strongly support these hypotheses (cf. Becker and Dietz, 2004). Moreover, negative effects related to too extensive cooperation activities are rarely reported in empirical studies. Most prominently, Uzzi (1996) highlights negative performance effects related to “overembeddedness” into networks. His argument and empirical evidence alludes to a strong reliance on few but very intensive relations, though. Brouwer et al. (1993) do not find a relationship between firms’ R&D cooperation and employment growth. In the context of subsidized cooperation Fornahl et al. (2011) show that intensive engagement in cooperative subsidies does not increase firms’ patenting performance.

As pointed out before, negative effects related to cooperation can have different causes including free-riding on partners’ R&D efforts (Kesteloot and Veugelers, 1995) and knowledge “leakages” (De Bondt et al., 1992). It is also important that cooperating partners fit to each other implying complementary resources and capabilities as well as a shared understanding of the project’s aims (Faems et al., 2005). The choice of the right cooperation partner is central in this respect (Fornahl et al., 2011). We pointed out before that non-subsidized cooperation might be quite different from subsidized cooperation as firms’ are less free in choosing the most appropriate partner in the latter case. One might therefore speculate that it is a problematic selection / combination of firms’ cooperation partners that explains the observed negative effects.

We further explore this issue in **model 7** that includes variables approximating the share of universities (UNI), the share of research organizations (RESEARCH), and the share of firms (FIRMS) in firms’ ego-networks, i.e. their direct links in subsidized cooperation projects. The first thing to notice is the positive significance of CPROJ in the second lag while the variable is still negative in the first lag. This is however a statistical artifact that relates to some incorrectly modeled autocorrelation dynamics in the original model. When including the second lag of the dependent variable ($LOGEMP_{t-2}$) the significance of CPROJ’s second lag disappears. This will be discussed in more detail in the next subsection.

In addition to CPROJ, also the share of research organizations (RESEARCH) becomes significant. The variable’s coefficient is positive and indicates that firms’ benefit from intensive cooperation with (public) research organizations. Most notably, this includes institutes of the Max-Planck and Fraunhofer Society that represent the majority of links in this category. The finding extents previous studies in the literature that find firms to benefit from unsubsidized cooperation with research organizations (cf. Beise and Stahl, 1999; Ponds et al. 2010; Veugelers and Cassiman 2005) to the case of subsidized relations. The positive effect of RESEARCH partly confirms our **hypothesis 4** according to which relations to universities and research organizations are most beneficial. The confirmation is only partly as we do not find any statistical evidence for a growth promoting role of links to universities, for which rich empirical evidence exists (Jaffe, 1989; Cassia et al., 2009).

We have to reject **hypothesis 5** as we do not observe a significant coefficient for DIST approximating the average distance of firms’ direct links. It means that geographic proximity does not influence the effectiveness of subsidized R&D cooperation for employment growth. Although we now control for the institutional and geographic composition of firms’ ego-networks CPROJ remains significant. Accordingly, the negative effects related to extensive cooperation are independent of these two aspects. Surely, this is an interesting issue for future research.

5.2 Firm size differences

In **hypothesis 6** we put forward that subsidies and subsidized cooperation are likely to be of varying importance for firms with different sizes. We particularly expect differences to exist between small and large firms. To test this, the sample of 2.199 firms is split into a sample of small firms with less than 100 and those with more than 100 employees (splitting our sample into two parts of similar size). As in particular very small firms might be quite different, we alternatively consider a third subsample consisting of firms with less than 50 employees. The previous empirical analysis (**model 8**) is repeated separately for the three subsamples. The results are presented in Table A3 in the Appendix. All estimated models are similar to **model 8** in terms of coefficients and significance of non-subsidies based variables. We therefore refrain from discussing these.

The estimation of models for the sample of firms with at least 100 employees requires the inclusion of the second lag of the dependent variable ($LOGEMP_{t-2}$) to avoid significant second-order autocorrelation. We pointed out above that the antipodal coefficient of CPROJ's second lag disappears when considering the second lag of the dependent variable in the model for the full population (see **model 7** and **8**). Accordingly, this observation seems to be driven by differences between the autocorrelation structure of large and small firms' employment growth. This provides support for **model 8** being empirically more reliable than **model 7**.

Concerning the two subsidies variables that gained significance in **model 8** (complete firm population), CPROJ and RESEARCH, we find that the latter one does not obtain a significant coefficient in any of the models for the above subsamples implying that its influence is not particularly related to these firm size class. In addition, to RESEARCH's significance in the model for the complete firm population (**model 8**) it also becomes positive significant in a (not reported) model that restrict the sample of firms to those with at least 50 employees. The variable however looses its significance again when considering only firms with 100 employees implying that there is no systematic relationship with firm size.

In the model for firms with at least 100 employees, FIRM is positively significant in the third lag. The positive coefficient suggests that FIRM is not simply picking up the effect of RESEARCH as both are strongly negatively correlated when restricting the sample to firms that receive cooperative subsidies (r=-0.47***). The finding means that larger firms tend to benefit from collaborating with other firms.

However, there might be an alternative explanation. FIRM is highly positively correlated with DIST (r=0.854***). Therefore, we suspect that FIRM captures negative effects related to intensive cooperation with organizations in spatial proximity. It is often argued that particularly cooperation with local and regional organization can yield benefits.(see for a discussion Boschma, 2005; Broekel et al., 2010). We test this alternative explanation by excluding FIRM from the regressions for firms with at least 100 employees. DIST becomes positive significant in the third lag implying that there seems to be some relevance to this explanation.[8]

For firms with at least 100 employees, we again observe the negative effect related to the number of cooperative projects (CPROJ), which is also visible in the models for the complete firm population. Similar is not observed in the models for small firms (less than 50

[8] To economize on space these results are not reported but can be obtained from the authors upon request.

and less than 100 employees). The negative relation between CPROJ and employment growth is therefore primarily relevant for larger firms.

There are many reasons for why extensive cooperation can yield negative effects on firm growth, e.g., free-riding, learning races, lack of flexibility and adaptability (see Section 2). However, these do not seem to be particularly more relevant for large than for small firms. We furthermore only explore the effects of subsidized R&D cooperation implying that the relationships might be very different for non-subsidized cooperation.

In light of this, we argue that the negative effects large firms experience when being extensively engaged in subsidized R&D cooperation are more likely to be caused by a suboptimal choice of cooperation partners and knowledge leakages. Starting with the latter, some large firms engage in a huge number of (subsidized) cooperation projects. One firm in our sample (a very large one) simultaneously cooperates with 551 organizations. These cooperative projects are distributed among different business units and technologies. It might very well be the case that the firm is cooperating in one field with a firm that is its direct competitor in another field. Given the convoluted structure of many large firms such may result in unintended knowledge spillovers and knowledge leakages that can reduce firm growth (cf. De Bondt et al., 1992).

Another potential reason for negative effects associated to extensive cooperation activities is the choice of partners. In contrast to non-subsidized cooperation, firms are not completely free in choosing their partnering organizations when applying for a joint project grant. In many instances, subsidies programs are precisely designed to stimulating cooperation between particular types of organizations. Just to name one example, the German BioRegio program provides subsidies for cooperation in R&D projects that are formed between organizations located within the same geographical region (cf. Dohse, 2000). It could therefore be argued that such and similar interference on firms' cooperation behaviour reduce the benefits of cooperation or even results in negative effects.[9] However, this remains speculative at the moment as this is beyond the present study. It clearly asks for future research.

One more variable gains significance in the model for firms larger than 100 employees, namely SPROJ. The variable represents the number of non-cooperative projects. Its first lag becomes positive significant only in the model for firms with at least 100 employees. It suggests that large firms' growth can be facilitated with non-cooperative subsidies. This is interesting as in the same model the number of cooperative projects is negative significant (see above), which clearly highlights differences in the effects of the two forms of R&D subsidies. The finding supports the positive evaluation of subsidies for firm performance in the literature (cf. Girma et al., 2008; Czarnitzki et al., 2007).

All the above results clearly confirm **hypothesis 6** according to which the relationship between R&D subsidies, cooperation networks, and firm growth differs significantly between firm size classes. This particularly concerns the importance of cooperation with different types of organizations (universities, research organizations, firms), which we find to vary strongly between small and large firms.

[9] Another prominent interference is the preference of links between organizations located in different member states of the EU in the fifth Framework program (Cf. Scherngell and Barber, 2011).

6 Conclusion

The present paper investigated the relevance of R&D subsidies for firm growth. It particularly contributed to the existing literature by differentiating between cooperative and non-cooperative R&D subsidies, which are shown to have distinct effects. Moreover, firms' embeddedness into subsidized cooperation networks was evaluated with respect to its importance for employment growth.

Concerning the empirical results, we did not find any indication that the granted (monetary) amounts of R&D subsidies matter. All observed significant effects relate to the number of subsidized projects a firm is engaged in. Neither the total amounts of received subsidies, nor the size of subsidized projects (as approximated by the average monetary amount of an individual grant) were found to impact firm growth. For policy evaluation, our findings imply that the effectiveness of programs is less related to the invested resources as to the actual specification of the program in terms of the number of supported projects, their cooperative character, as well as the particular type of cooperation that are supported.

Evidence was provided that the number of subsidized non-cooperative projects a firm is involved in can stimulate its growth, at least in case of large firms with more than 100 employees. This implies that policy should rather initiate a great number of small projects instead of focusing the monetary support on few large-scale projects.

Interestingly, we found the number of subsidized cooperative projects a firm is engaged in being related to significant negative effects on firms' (and in particular large firms') employment growth. This finding contrasts the growing importance of this type of subsidies in recent years (see Broekel and Graf, 2011).

Our findings however provide some evidence that if subsidies for cooperation aim at supporting interactions between firms and research organizations they can yield positive effects. The same is true when subsidized joint projects connect large firms to other firms located at larger geographical distances. Accordingly, our study highlights the importance of the particular design of R&D support policies. Clearly a "one size fits all" approach to R&D subsidies programs will yield suboptimal results.

The presented study has a number of shortcomings that need to be pointed out. Amongst these is its focus on the *direct* relationship between R&D subsidies and employment growth. It can very well be argued that R&D subsidies primarily aim at enhancing firms' innovative capacities, which do not necessarily influence firms' employment growth. This implies that we probably underestimated the effects of R&D subsidies.

For the empirical analysis we pooled the data for firms active in a wide range of industries. It seems to be more than likely that significant inter-industrial differences exist in the effectiveness and relevance of such subsidies. For instance, R&D subsidies are likely to be of larger importance in research-intensive industries. The employed data also covers only support programs by the German federal government. Support from inter-national organizations (e.g. EU) might have very distinct effects that are not considered in this study. The same might hold for programs initiated at sub-national levels (regions, districts, cities). These issues clearly lay the path for future research.

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Appendix

No.	EMP	PROD	SUBS	SUBSP	PROJ	SUM	CSUM	SUMP	CSUMP	SPROJ	CPROJ	DEGREE	BETW	UNI	RESEARCH	FIRM
EMP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PROD	0.000 (0.966)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBS	0.768 (0.000)	-0.001 (0.913)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBSP	0.126 (0.000)	-0.001 (0.865)	0.339 (0.000)	-	-	-	-	-	-	-	-	-	-	-	-	-
PROJ	0.861 (0.000)	-0.002 (0.826)	0.925 (0.000)	0.319 (0.000)	-	-	-	-	-	-	-	-	-	-	-	-
SUM	0.628 (0.000)	-0.001 (0.926)	0.928 (0.000)	0.355 (0.000)	0.812 (0.000)	-	-	-	-	-	-	-	-	-	-	-
CSUM	0.789 (0.000)	-0.001 (0.914)	0.962 (0.000)	0.297 (0.000)	0.923 (0.000)	0.790 (0.000)	-	-	-	-	-	-	-	-	-	-
SUMP	0.169 (0.000)	-0.001 (0.930)	0.407 (0.000)	0.739 (0.000)	0.354 (0.000)	0.538 (0.000)	0.274 (0.000)	-	-	-	-	-	-	-	-	-
CSUMP	0.164 (0.000)	-0.002 (0.793)	0.326 (0.000)	0.720 (0.000)	0.331 (0.000)	0.210 (0.000)	0.380 (0.000)	0.205 (0.000)	-	-	-	-	-	-	-	-
SPROJ	0.714 (0.000)	-0.001 (0.881)	0.853 (0.000)	0.374 (0.000)	0.882 (0.000)	0.860 (0.000)	0.770 (0.000)	0.531 (0.000)	0.243 (0.000)	-	-	-	-	-	-	-
CPROJ	0.859 (0.000)	-0.002 (0.816)	0.894 (0.000)	0.277 (0.000)	0.982 (0.000)	0.740 (0.000)	0.925 (0.000)	0.261 (0.000)	0.345 (0.000)	0.778 (0.000)	-	-	-	-	-	-
DEGREE	0.873 (0.000)	-0.001 (0.874)	0.872 (0.000)	0.238 (0.000)	0.971 (0.000)	0.730 (0.000)	0.898 (0.000)	0.254 (0.000)	0.283 (0.000)	0.792 (0.000)	0.980 (0.000)	-	-	-	-	-
BETW	0.865 (0.000)	-0.001 (0.925)	0.836 (0.000)	0.135 (0.000)	0.922 (0.000)	0.700 (0.000)	0.860 (0.000)	0.207 (0.000)	0.153 (0.000)	0.757 (0.000)	0.928 (0.000)	0.943 (0.000)	-	-	-	-
UNI	0.084 (0.000)	-0.001 (0.895)	0.119 (0.000)	0.305 (0.000)	0.202 (0.000)	0.096 (0.000)	0.126 (0.000)	0.128 (0.000)	0.347 (0.000)	0.166 (0.000)	0.203 (0.000)	0.164 (0.000)	0.070 (0.000)	-	-	-
RESEARCH	0.072 (0.000)	-0.006 (0.472)	0.124 (0.000)	0.353 (0.000)	0.201 (0.000)	0.081 (0.000)	0.145 (0.000)	0.107 (0.000)	0.462 (0.000)	0.104 (0.000)	0.226 (0.000)	0.179 (0.000)	0.070 (0.000)	0.162 (0.000)	-	-
FIRM	0.122 (0.000)	-0.003 (0.727)	0.176 (0.000)	0.428 (0.000)	0.316 (0.000)	0.115 (0.000)	0.205 (0.000)	0.134 (0.000)	0.579 (0.000)	0.169 (0.000)	0.354 (0.000)	0.305 (0.000)	0.124 (0.000)	0.331 (0.000)	0.448 (0.000)	-
DIST	0.134 (0.000)	-0.001 (0.953)	0.189 (0.000)	0.448 (0.000)	0.316 (0.000)	0.131 (0.000)	0.215 (0.000)	0.154 (0.000)	0.602 (0.000)	0.183 (0.000)	0.348 (0.000)	0.295 (0.000)	0.123 (0.000)	0.421 (0.000)	0.592 (0.000)	0.854 (0.000)
Standard errors in parentheses			*** p<0.01, ** p<0.05, * p<0.1													

Table A1: Correlation matrix

Full Models	1	2	3	4	5	6	7	8
VARIABLES	logEMP	logEMP	logEMP	logEMP	logEMP	logEMP	logEMP	logEMP
Log(EMP)t-1	1.050*** (0.0334)	1.112*** (0.0672)	1.066*** (0.0545)	1.054*** (0.0365)	1.000*** (0.023)	1.017*** (0.0312)	1.014*** (0.0213)	1.125*** (0.101)
Log(EMP)t-2	-	-	-	-	-	-	-	-0.134 (0.0979)
Log(PROD)t	0.113** (0.0531)	0.143** (0.0643)	0.122* (0.0649)	0.0968* (0.0532)	0.0899* (0.0509)	0.0889* (0.048)	0.0719 (0.0443)	0.0598 (0.0696)
2004	-0.0223* (0.0136)	-0.0205 (0.0154)	-0.0208 (0.0147)	-0.0223* (0.0135)	-0.0220* (0.0132)	-0.0254* (0.0139)	-0.0317** (0.013)	-0.0382** (0.0152)
2005	-0.0773 (0.0652)	-0.0655 (0.0718)	-0.062 (0.0699)	-0.0751 (0.0649)	-0.0813 (0.0642)	-0.0921 (0.0653)	-0.130** (0.0602)	-
2006	-0.0312 (0.0503)	-0.0175 (0.0553)	-0.0208 (0.0541)	-0.0296 (0.0495)	-0.037 (0.0484)	-0.0462 (0.0501)	-0.0681 (0.0463)	-0.0949* (0.0543)
2007	-0.0469 (0.0334)	-0.0362 (0.0374)	-0.0393 (0.0358)	-0.039 (0.034)	-0.0448 (0.0334)	-0.0482 (0.0343)	-0.0648** (0.0322)	-0.0862** (0.0364)
2008	-0.0015 (0.0199)	0.0004 (0.0217)	0.0037 (0.0212)	-0.0002 (0.0199)	-0.0041 (0.0198)	-0.0068 (0.0201)	-0.0195 (0.0184)	-0.0212 (0.0203)
SUBSt-1	-2.80e-08 (2.56e-08)	-	-	-	-	-	-	-
SUBSt-2	-7.65e-08* (4.23e-08)	-	-	-	-	-	-	-
SUBSt-3	4.26e-08 (4.08e-08)	-	-	-	-	-	-	-
SUBSPt-1	-	5.76e-07 (7.48e-07)	-	-	-	-	-	-
SUBSPt-2	-	-9.18e-07 (8.72e-07)	-	-	-	-	-	-
SUBSPt-3	-	-3.06e-07 (4.85e-07)	-	-	-	-	-	-
PROJt-1	-	-0.0076 (0.0174)	-	-	-	-	-	-
PROJt-2	-	0.0176 (0.0174)	-	-	-	-	-	-
PROJt-3	-	-0.0253* (0.0142)	-	-	-	-	-	-
SUMt-1	-	-	-4.83e-08 (6.37e-08)	-	-	-	-	-
SUMt-2	-	-	-1.01e-07 (7.07e-08)	-	-	-	-	-
SUMt-3	-	-	2.02e-08 (1.27e-07)	-	-	-	-	-
CSUMt-1	-	-	-6.11e-09 (2.00e-07)	-	-	-	-	-
CSUMt-2	-	-	-1.26e-08 (2.43e-07)	-	-	-	-	-
CSUMt-3	-	-	-4.41e-08 (9.57e-08)	-	-	-	-	-
SUMP_Pt-1	-	-	-	4.80e-07 (5.67e-07)	-2.42e-08 (7.14e-07)	1.06e-07 (5.64e-07)	-7.09e-08 (3.42e-07)	-7.19e-07 (7.61e-07)
SUMP_Pt-2	-	-	-	-2.78e-07 (5.07e-07)	2.59e-07 (5.09e-07)	1.91e-07 (4.08e-07)	3.39e-07 (3.67e-07)	3.35e-07 (3.94e-07)
SUMP_Pt-3	-	-	-	-2.26e-08 (3.48e-07)	-3.81e-07 (3.02e-07)	-2.54e-07 (2.63e-07)	-4.34e-07 (3.81e-07)	-1.12e-07 (3.44e-07)
CSUMP_Pt-1	-	-	-	-2.39e-07 (5.87e-07)	5.62e-07 (5.04e-07)	7.35e-08 (4.50e-07)	2.75e-07 (6.15e-07)	9.15e-07 (1.24e-06)
CSUMP_Pt-2	-	-	-	1.35e-09 (5.02e-07)	1.43e-07 (3.73e-07)	-2.26e-08 (3.67e-07)	-4.70e-07 (7.18e-07)	-8.03e-07 (9.78e-07)
CSUMP_Pt-3	-	-	-	-2.05e-07 (4.18e-07)	-2.64e-07 (3.18e-07)	-1.16e-07 (3.82e-07)	2.17e-07 (4.64e-07)	2.41e-07 (4.42e-07)

Table A2: R&D subsidies and employment growth - all time lags

SPROJt-1	-	-	-	0.0231 (0.0527)	0.0326 (0.055)	0.0534 (0.0437)	0.039 (0.0385)	0.0589 (0.0416)
SPROJt-2	-	-	-	-0.0156 (0.0219)	-0.030 (0.0297)	-0.0241 (0.0309)	-0.0178 (0.0155)	-0.0164 (0.0224)
SPROJt-3	-	-	-	-0.0384 (0.0365)	0.0012 (0.0359)	-0.021 (0.0404)	-0.0166 (0.0261)	-0.0365 (0.0352)
CPROJt-1	-	-	-	-0.0266** (0.0123)	-0.0169 (0.0646)	-0.0251 (0.024)	-0.0193** (0.0092)	-0.0272** (0.0128)
CPROJt-2	-	-	-	0.0386 (0.024)	0.0138 (0.0472)	0.023 (0.0191)	0.0361* (0.0204)	0.0459 (0.0317)
CPROJt-3	-	-	-	-0.0142 (0.0184)	-0.0123 (0.0277)	-0.0177 (0.0254)	-0.0222 (0.0147)	-0.0207 (0.0264)
DEGREEt-1	-	-	-	-	0.0005 (0.0075)	-	-	-
DEGREEt-2	-	-	-	-	0.0016 (0.0043)	-	-	-
DEGREEt-3	-	-	-	-	-0.0004 (0.0033)	-	-	-
BETWt-1	-	-	-	-	-	3.75e-06 (9.52e-06)	-	-
BETWt-2	-	-	-	-	-	1.01e-06 (3.07e-06)	-	-
BETWt-3	-	-	-	-	-	6.35e-07 (4.10e-06)	-	-
UNIt-1	-	-	-	-	-	-	-0.0308 (0.369)	0.149 (0.343)
UNIt-2	-	-	-	-	-	-	-0.196 (0.212)	-0.476 (0.382)
UNIt-3	-	-	-	-	-	-	0.161 (0.151)	0.347 (0.317)
RESEARCHt-1	-	-	-	-	-	-	-0.0699 (0.410)	0.212 (0.511)
RESEARCHt-2	-	-	-	-	-	-	-0.486 (0.383)	-0.632 (0.408)
RESEARCHt-3	-	-	-	-	-	-	0.400** (0.186)	0.407* (0.221)
FIRMt-1	-	-	-	-	-	-	0.111 (0.175)	-0.0249 (0.190)
FIRMt-2	-	-	-	-	-	-	-0.123 (0.154)	-0.141 (0.211)
FIRMt-3	-	-	-	-	-	-	0.118 (0.118)	0.147 (0.157)
DISTt-1	-	-	-	-	-	-	0.0002 (0.0004)	-0.0001 (0.0006)
DISTt-2	-	-	-	-	-	-	0.0003 (0.0004)	0.0006 (0.0006)
DISTt-3	-	-	-	-	-	-	-0.0004 (0.0003)	-0.0005 (0.0004)
Constant	44.01 (27.4)	39.83 (31.12)	40.85 (29.71)	44.06 (27.28)	43.76 (26.67)	50.50* (27.99)	63.23** (26.19)	76.48** (30.72)

Table A2a: R&D subsidies and employment growth - all time lags (addition to 1a)

Observations	11101	11101	11101	11101	11101	11101	11101	11101
Number of firms	2189	2189	2189	2189	2189	2189	2189	2189
No.instruments	47	48	46	66	76	76	106	95
AR (1)	-3.964	-3.862	-3.934	-3.939	-3.961	-3.967	-4.025	-3.1
AR (1) p-value	7.36E-05	0.000112	8.35E-05	8.18E-05	7.47E-05	7.28E-05	5.69E-05	2.00E-03
AR (2)	1.585	1.59	1.579	1.541	1.55	1.544	1.624	1.61
AR (2) p-value	0.113	0.112	0.114	0.123	0.121	0.123	0.104	0.108
Obs/group avg	5.071	5.071	5.071	5.071	5.071	5.071	5.071	4.08
Obs/group max	6	6	6	6	6	6	6	5
Obs/group min	1	1	1	1	1	1	1	1
Wald chi2	4145	2840	2546	22482	74004	68627	98541	70054.33
Wald chi2 p-value	0	0	0	0	0	0	0	0
Hansen	31.06	20.5	24.22	26.66	41.34	40.08	54.32	52.16
Hansen p-value	0.703	0.967	0.836	0.99	0.877	0.905	0.958	0.833
Sargan	32.3	25.08	27.04	39.4	45.9	46.76	70.99	45.06
Sargan p-value	0.645	0.867	0.716	0.743	0.745	0.714	0.578	0.957
St.errors in parenth. *** p<0.01, ** p<0.05, * p<0.1								

Table A2b: R&D subsidies and employment growth - all time lags (addition to 1 and 1a)

	<50	<100	>100
VARIABLES	logEMP	logEMP	logEMP
Log(EMP)t-1	0.8300*** (0.0748)	0.8700*** (0.0703)	1.0540*** (0.0770)
Log(EMP)t-2	0.0114 (0.0573)	0.0440 (0.0462)	-0.0039 (0.0788)
Log(PROD)t	-	-	-0.0829 (0.0617)
2004	0.0002 (0.0002)	0.0101 (0.0256)	-0.0705*** (0.0189)
2005	-0.0353* (0.0197)	0.0114 (0.1210)	-
2006	0.0013 (0.0277)	0.0441 (0.0955)	-0.2160*** (0.0658)
2007	-0.0013 (0.0189)	0.0101 (0.0666)	-0.1670*** (0.0418)
2008	0.0098 (0.0173)	0.0141 (0.0397)	-0.0603*** (0.0225)
SUMPt-1	6.26e-07 (2.74e-06)	-8.28e-08 (2.38e-07)	-9.96e-07 (7.18e-07)
SUMPt-2	-3.72e-07 (7.07e-07)	8.63e-08 (2.91e-07)	2.02e-07 (4.47e-07)
SUMPt-3	-2.60e-07 (3.57e-07)	6.19e-08 (3.73e-07)	7.79e-08 (3.43e-07)
CSUMt-1	3.66e-07 (2.12e-06)	1.22e-06 (1.45e-06)	7.40e-07 (7.12e-07)
CSUMt-2	6.33e-07 (8.64e-07)	6.48e-08 (1.05e-06)	-3.77e-07 (8.29e-07)
CSUMt-3	2.26e-07 (1.05e-06)	-4.37e-07 (6.56e-07)	1.33e-07 (5.62e-07)
SPROJt-1	-0.0538 (0.1440)	0.1030 (0.1140)	0.0612* (0.0372)
SPROJt-2	0.1060 (0.0885)	-0.0351 (0.1070)	-0.0226 (0.0232)
SPROJt-3	-0.0367 (0.0523)	-0.0687 (0.0586)	-0.0223 (0.0406)
CPROJt-1	-0.0013 (0.0597)	0.0660 (0.0628)	-0.0240* (0.0130)
CPROJt-2	0.0129 (0.0261)	-0.0051 (0.0433)	0.0262 (0.0245)
CPROJt-3	-0.0175 (0.0281)	-0.0688 (0.0589)	-0.0038 (0.0186)
UNIt-1	-0.1360 (0.5230)	0.0868 (0.4250)	0.0672 (0.1720)
UNIt-2	-0.3980 (0.3270)	-0.4700 (0.3380)	-0.2270 (0.1890)
UNIt-3	0.1040 (0.2450)	0.2950 (0.3060)	0.1440 (0.1510)
RESEARCHt-1	-0.0738 (0.3090)	-0.0316 (0.3680)	0.0775 (0.4020)
RESEARCHt-2	-0.4100 (0.4290)	0.0247 (0.3910)	-0.1310 (0.3010)
RESEARCHt-3	0.1650 (0.2670)	-0.0696 (0.3070)	0.2040 (0.1680)
FIRMt-1	0.1490 (0.4340)	-0.0471 (0.2300)	-0.1840 (0.1550)
FIRMt-2	-0.0179 (0.1620)	-0.0582 (0.1400)	-0.2730 (0.1770)
FIRMt-3	-0.0180 (0.1540)	0.0600 (0.1580)	0.2310** (0.1120)
DISTt-1	-0.0002 (0.0004)	3.94e-05 (0.0005)	0.0003 (0.0004)
DISTt-2	0.0004 (0.0004)	0.0003 (0.0004)	0.0004 (0.0005)
DISTt-3	-9.41e-05 (0.0004)	0.0002 (0.0004)	-0.0004 (0.0003)
Constant	0.0000 (0.0000)	-20.0300 (51.6400)	141.9000*** (38.3300)
Observations	2.552	4.46	5.288
Number of firms	500	879	1209
No. instruments	97	103	93
AR (1)	-2494	-2906	-2143
AR (1) p-value	0.0126	0.00366	0.0321
AR (2)	0.520	0.539	1428
AR (2) p-value	0.603	0.590	0.153
Obs/group avg	5104	5074	4099
Obs/group max	6	6	5
Obs/group min	1	1	1
Wald chi2	309265	987.8	70161
Wald(chi2p-v.)	0	0	0
Hansen	70.10	67.58	48.71
Hansen p-value	0.311	0.593	0.872
Sargan	62.87	58.02	36.65
Sargan p-value	0.552	0.866	0.994
St.errors in pare	*** p<0.01, ** p<0.05, * p<0.1		

Table A3: R&D subsidies and employment growth -size disaggregation

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