Effectiveness of R&D subsidies during the crisis: firm-level evidence across EU countries

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Abstract

This paper is one of the first attempts in the literature to evaluate the effectiveness of R&D policies in Europe during the great crisis of the late 2000s. Using homogenous firm-level data for the largest EU Member States over the period 2007-2009, we test whether manufacturing firms receiving public subsidies spent more on R&D. The analysis is performed using both non-parametric techniques and parametric estimation methods accounting for the possible endogenous selectivity of R&D subsidies. The hypothesis of full crowding-out is rejected in all countries under exam as firms did not replace their own resource with public grants. However, these firms did not allocate additional funds to research and hence, differently from earlier works, we do not find evidence for additionality effects of R&D subsidies. Our estimates indicate that, albeit not expansive, public subsidies to R&D thwarted the reduction of firm R&D effort in the aftermath of economic crisis.

Keywords: R&D; subsidies; policy evaluation; EU manufacturing firms

JEL codes: C21, D04, O32, O38

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1. Introduction

After the financial turmoil of 2008 and the consequent collapse of the markets, there has been an increasing effort of policy makers in identifying the institutional setting that promotes firm competitiveness, makes companies less sensitive to market turbulences and increases their ability to

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grow stably. Firms prone to innovation and international operations have been found to be more resistant to the crisis and achieve better productivity performance between 2008 and 2009 (Altomonte et al., 2013). This poses a serious challenge in the European Union as the majority of firms are medium- and small-sized, fall behind the world technology frontier, and have weak technological capabilities. The financial crisis has exacerbated constraints to firm innovation either by raising market uncertainty or imposing stricter conditions to access external funds. These factors have been particularly detrimental for R&D-performing firms as such companies rely more on external finance to undertake research activities (Brown et al., 2012; Maskus et al., 2012). It is therefore crucial to ascertain whether public policies supporting business R&D mitigated the harsher conditions to access the credit market in the aftermath of the crisis. This issue appears of primary importance in order to understand whether anti-cyclical R&D policies can effectively promote, or at least stabilize, firm engagement in research projects in periods of slump and higher uncertainty. Indeed, the fall of R&D investment along the business cycle, albeit temporary, may produce long-lasting negative effects on firm competitiveness as retarding the introduction of new products or production modes. On the aggregate, this may result into lower income or occupational outcomes. For instance, Brautzsch et al. (2015) have recently investigated the macroeconomic impact of the expansive R&D policy adopted in Germany during the latest crisis, finding considerably strong counter-cyclical effects of R&D subsidies.

Public policies to R&D are usually motivated on the basis of the gap between social and private returns, which leads firm to under-invest in R&D. This issue is object of a very popular stream of studies (Zùniga-Vicente et al., 2014; Becker, 2015). Results of this literature change in relation to the nature of R&D policy under assessment (subsidies, tax credits, soft-loans, etc.), country coverage, and time period. Cross-country comparisons on the effectiveness of R&D policies have been scant in the literature because of the lack of comparable data. Exploiting national sources, harmonized according to the standards of the Community Innovation Survey, Czarnitzki and Lopes Bento (2012) document for Belgium, Germany, Luxemburg and South Africa that firms would have invested significantly less in R&D if they had not received subsidies and, on aggregate, R&D activities would have increased significantly if government had extended R&D grants to non-supported firms. Apart from a few exceptions, cross-country evidence on the role of R&D policies in the latest years, and in particular during the great crisis, is still missing.

The present paper fills this gap of the literature making use of the *EFIGE* dataset (*European Firms in the Global Economy-EU EFIGE* survey) that collects survey information on manufacturing firms from the largest EU countries (France, Germany, Italy, Spain and the UK) observed between 2007 and 2009. The *EFIGE* dataset offers numerous information on firm characteristics and on contextual factors influencing the company decision to undertake R&D projects and to exploit public support to perform these activities. From this perspective, the comparability of our data across countries makes the present study almost unique within the strand of the literature on R&D policies.

The focus of our work is on those firms that did undertake R&D projects between 2007 and 2009 and hence we exclude non-innovative companies as well as those that did innovate without formal research activities. Specifically, we look at input additionality of R&D policies, i.e. whether public support to R&D effectively raised R&D effort of recipient firms. We do not consider the effect on other dimensions of firm performance such as patenting, innovative sales, productivity, etc. (i.e. output additionality) on the presumption that, if any, these effects take much longer to show up and hence the time frame of our analysis may result inadequate to this aim. Our interest is limited to direct subsidies to R&D as this kind of policy instruments is widely adopted in Europe and presents some common characteristics which make them comparable across countries, differently from other R&D public polices such as for instance fiscal incentives to R&D. For instance, whilst research subsidies are targeted to raise private marginal returns to R&D and are allocated selectively, tax incentives reduce the cost of doing research and are automatically disbursed to claimant firms. As a consequence, the procedures adopted for testing the additionality of tax credits are different from those used with R&D subsidies. The aim of the present paper is therefore of assessing how effective were public programmes that supported selectively business R&D in Europe at the time of the great market fall.

We identify the impact of R&D subsidies on company's research intensity through different methods of analysis that permit to address the main econometric issues affecting policy evaluation analyses. First, to deal with the problem of "selection on observables" we adopt a propensity score matching (PSM) procedure. Second, to account for the potential biases associated with the "selection on unobservables", we also carry out a parametric regression analysis based on a Heckman model that accounts for the possible endogenous selectivity between the firm propensity to invest in R&D and to benefit from R&D subsidies. It should be stressed that this paper exploits cross-sectional data and this prevents us from fully accounting for unobserved firm heterogeneity or persistency in firm engagement in R&D and in the usage of public support.[1] However, the availability of wide information on company characteristics reduces the risk of estimation bias associated with the cross-sectional nature of our data.

In the analysis, we consider two measures of outcome, namely total (gross of subsidies) and private (net of subsidies) R&D expenditure on total sales, in order to respectively check the

[1] The role of persistence in the allocation of public subsidies to business R&D activities is examined, among others, by Antonelli and Crespi (2013), Czarnitzki and Lopes Bento (2013) and Busom et al. (2016).

hypothesis of full/partial crowding-out (i.e. R&D policy did raise total research intensity) and the hypothesis of crowding-in/additionality (i.e. R&D policy did raise private research intensity). Our findings show that, in the EU countries under assessment, the intensity of total R&D expenditure was systematically higher for those firms benefiting from R&D subsidies, implying that private companies did not substitute their funds to R&D with public grants (no crowding-out). However, we show that public research grants did not induce firms to spend additional (own) resources on R&D. In other words, there were no systematic differences in the intensity of R&D investment, net of public provisions, between supported and not supported firms (no crowding-in/additionality). The latter finding suggests that, albeit not expansive, public subsidies to R&D thwarted the reduction of firm R&D effort at the outset of financial turmoil, probably mitigating the stricter financial constraints that firms had to face in order to fund R&D and other risky activities.

The remainder of the paper is organized as follows. Section 2 briefly illustrates evidence on the effect of R&D subsidies among the EU countries under examination. Section 3 presents the dataset and describes the variables employed in the analysis. In Section 4 we perform PSM and parametric estimation analyses and quantify the effect of public subsidies on R&D intensity, distinguishing between the value of research expenditure gross and net of public subsidies. Finally, Section 5 discusses the results and concludes.

2. The impact of public subsidies on business R&D: a brief survey

Public policies to support private R&D efforts are justified by the presence of market failures which make private returns on R&D investments lower than their social value. Due to their public nature, most research outcomes are difficult to appropriate and, hence, private firms invest in R&D less than would be socially desirable. Market failures also arise because research projects are highly risky and R&D performing firms find it particularly difficult to obtain external funding, such as bank credit, to support these tasks.

While the rationale for R&D policies is widely recognized, there is less agreement on their effectiveness. Firstly, empirical findings often change with the firm performance under assessment, i.e. the policy beneficiaries may increase innovation inputs (R&D expenditures), innovation outputs (e.g. patents) or economic performance (e.g. productivity). Secondly, different policy instruments, such as R&D subsidies, tax allowances, public procurements, or incentives to collaborative research, may affect the company performance along different dimensions.

The main difficulty in evaluating R&D (as well as other) policies is due to the presence of selectivity bias as companies benefiting from public support are not randomly chosen. First of all, they need to apply for research subsidies and, hence, a self-selection process may take place. Then, beneficiaries of R&D subsidies are selected among several applicants by a public agency which, for instance, could adopt a 'picking the winners' strategy. To overcome these selectivity problems, studies aimed at assessing the effectiveness of public support to business R&D have used different methods of analysis. The most diffused approach is the matching procedure. This is a non-parametric method which evaluates whether the mean difference of R&D expenditures (or their intensity on total sales) between firms getting public support and unsupported firms, identified on the basis of some common observable characteristics, can be ascribed to the policy treatment. However, in presence of unobservable factors affecting the likelihood of receiving a public support, matching methods yield biased estimates, as public support may be potentially endogenous to firm R&D efforts. Parametric approaches circumventing the 'selection on unobservables' problem are the Selection model, the Instrumental-Variables (IV) and the Difference-in-differences (DID) regressions[2].

The literature on the effectiveness of R&D subsidies is very extensive and has been surveyed by several papers. David et al. (2000) discusses pros and cons of research subsidies surveying the early wave of these studies. Their main conclusion is that, until the late 1990s, firm-level evidence was not very supportive of the additionality hypothesis for public subsidies to R&D, as this policy instrument often crowds out private effort. In the latest years, evidence looks more favourable about the expansive effect of public grants to business R&D (see Becker, 2015). According to García-Quevedo (2004) and, more recently, Zùniga-Vicente et al. (2014), almost half of the micro-econometric studies support the additionality hypothesis for advanced countries.

TABLE 1 ABOUT HERE

Table 1 details recent firm-level studies on the impact of R&D subsidies in the European countries covered by the present paper. Due to the lack of data on the amount of subsidies obtained by each company, half of these studies consider total R&D expenditure (or intensities) as outcome variable; as a consequence, they cannot test the additionality hypothesis but only that of full

[2] See Cerulli (2010) for a review of the different micro-econometric methods used for estimating the effect of public supports on business R&D. Valuable novel contributions can be found in the latest literature. Using data for Finnish firms, Takalo et al. (2013) estimate a structural model of R&D subsidies in which both the firm decision to apply for public R&D grant and the extent of financial support disbursed by the public agency are jointly modelled. However, contrary to most studies surveyed in the present paper (see Table 1), these authors estimate the effect of subsidies on planned rather than realized R&D investments. To identify the impact of different subsidy levels on the R&D expenditures of Irish firms, Gorg and Strobl (2007) combine a matching approach with a DID estimation approach. They find a positive impact only for small grants which are allocated to domestic firms. Another procedure to control for the endogeneity of subsidies is that of Regression Discontinuity Design (RDD) which, under given conditions, is equivalent to a randomized experiment. Bronzini and Iachini (2014) employ this procedure with a sample of Italian firms that applied for innovation subsidies granted by a regional agency on a competitive basis. These authors compare the extent of innovation investments between subsidized companies and those that were not subsidized but achieved a score close to the threshold established to be eligible for a grant; they find a positive impact of public subsidies on innovation performance only for small-sized firms.

crowding-out. In summary, most studies find that public subsidies have positively affected business R&D, but only few works document that firms increased their research effort more than the amount of R&D grants received. It must be stressed that, with the only exception of Hud and Hussinger (2015), all these studies are based on data for the 1990s or the early 2000s, so that they do not account for the effect on business R&D exerted by the 2008 economic crisis. According to Schumpeter, innovative activities are carried out in a cumulative fashion by existing firms (incumbents) that invest systematically in R&D during expansions. Conversely, over downturns, new or emerging firms introduce radical innovations and, in this way, they contribute to revert the cycle at the macroeconomic level. Archibugi and Filippetti (2011) term these two alternative modes of innovation as *creative accumulation* and *creative destruction*[3]. Innovative activities can be counter-cyclical and speed-up the exit from recessions also for other reasons: Barlevy (2007) and Rafferty and Funk (2004) argue that the opportunity cost of undertaking long-term investment, such as those in R&D, is lower during economic downturns as opposed to the phases of expansion. However, at the same time, innovative investment may decline in times of crisis because of a reduction of both internal and external sources of finance. Aghion et al. (2012) find that R&D expenditures are counter-cyclical for firms without credit constraints, but they are strongly pro-cyclical for those facing tight credit conditions and depending more on external funds. Thus, as far as the latter firms prevail among those performing R&D, on aggregate, business research expenditures decrease during recessions. Such a reduction of innovative efforts may have permanent effects on productivity growth and, hence, justify anti-cyclical policies aimed at stabilizing R&D investment.

TABLE 2 ABOUT HERE

Table 2 reports the rates of change in business R&D at the economy-wide level and shows that this type of investments decreased in the aftermath of the crisis in all the EU countries under assessment. France represents a valuable exception as experiencing a stable increase in business R&D, even in 2008. After 2010, the rate of change in business R&D recovered to the pre-crisis levels in Germany and the UK (as well as in the EU28), but not in Italy and Spain where it remained negative. The latest trend in business R&D of the latter countries was in part due to the hard fiscal consolidation which prevented them from implementing expansive policies to support research and innovation (OCED, 2012; Veugelers, 2014).

[3] Using CIS micro-data for UK, Archibugi et al. (2013) assess to what extent innovation expenditures are driven by a process of creative accumulation or destruction.

On the contrary, to contrast the negative consequences of the crisis, the German federal government increased the budget for one of its largest R&D subsidy programs (the "Central Innovation Program for SMEs" - ZIM) by € 900 million between 2009 and 2010. By means of an input-output analysis, Brautzsch et al. (2015) show that such a program reduced by 0.5% the decline of German GDP in 2009 while it contributed by 1.5% to the GDP recovery in 2010. In the same vein, France introduced a very generous tax credit for business R&D in 2008: this was based on the volume of research expenditures and allowed a 30% rate of tax reduction (Mulkay and Mairesse, 2013). The impact exerted by such a policy measure seems substantial: in fact, while in all the EU countries private R&D investments declined in 2009, they increased in France. Hud and Hussinger (2015) analyse the R&D performance of German SMEs from 2006 to 2010, detecting additionality effects of public research grants, apart from the year 2009 in which they find evidence for (partial) crowding-out. As long as R&D is strongly pro-cyclical for credit-constrained and smaller firms (i.e. those having a higher propensity to apply for R&D subsidies), these companies are more likely to cut or postpone their R&D investment plans during recessions. Consistently, Hud and Hussinger show that the effect of research subsidies was again positive in 2010, i.e. immediately after the crisis' peak (though smaller than in the years 2006-2008).

On the basis of this overview, the research questions that we will seek to address in the paper are the following: 1) Did public subsidies to R&D increase or, at best, avoid a reduction in business research more severe than the one recorded in 2009 in the major countries of the EU? 2) Were there significant differences across EU countries in the effectiveness of R&D subsidies?

Before addressing these questions, it is important to summarize the main traits of the policy measures to support business R&D adopted by the European countries examined in the present paper. In the UK, direct subsidies are by far less diffused than fiscal incentives, which are the main instrument to support business R&D (accounting for 75% of government budget to innovation). In Italy, direct subsidies to private R&D are provided by the central government through the Ministry of Research's funding scheme and by regional governments. In addition to R&D subsidies, a tax credit proportional to the volume of R&D expenditures was introduced in 2007 (Cantabene and Nascia, 2014). In France, the generosity of direct funding to business R&D has not changed remarkably since the mid-2000s, while that of research tax credits has dramatically increased: a new, more generous regime of tax credit has been introduced since 2008. In that year, direct subsidies and fiscal incentives accounted for 12% and 18% of total private R&D. In Spain, tax incentives and direct supports (subsidies and loans) have been both available since the 1980s, although a major legal change increasing tax incentives was introduced in 1995 (Busom et al., 2016). Direct subsidies from central government are mostly channeled through a public agency providing grants and loans. Further schemes of direct R&D funding are provided by regional governments. Germany is the only country without R&D tax incentives and hence supports business research exclusively through non-repayable cash grants, R&D loans and guarantees. These public incentives are dispensed by governments or development banks at federal and state level (*Länder*), and are generally targeted to SMEs.

3. Data description and summary statistics

Our study exploits the EU-EFIGE/Bruegel-UniCredit (henceforth EFIGE) dataset, which collects survey data for a representative sample of manufacturing firms from seven EU countries over the period 2007-2009 (Altomonte and Aquilante, 2012)[4]. Our attention is restricted to the largest countries included in the sample, namely France, Germany, Italy, Spain, and the UK; together, according to Eurostat statistics, they accounted for 73% of business R&D in the EU in the period under exam.

Table 3 illustrates the number of firms sampled in the EU countries covered by the survey that reported a positive share of R&D expenditures on total sales[5]. To discriminate between firms benefiting or not from R&D public subsidies, we consider those companies declaring to receive some form of R&D public support (the question was "Did the firm benefit from tax allowances and financial incentives for these R&D activities) and restrict the focus on those for which it is possible to infer the amount of R&D grant received on the basis of the following question "How have R&D activities been financed on average in the last three years (2007-2009)?". As possible answers (self-financing, bank credit, venture capital, etc.), surveyed firms were asked to indicate the share of public funds on total R&D expenses. In practice, we identify as subsidized firms those reporting a positive share of public funds to R&D on the presumption that respondents did not include tax incentives among the sources of finance for R&D. Indeed, the amount and the mix of financial resources necessary to develop research projects are known before their implementation and often this is a necessary requirement to apply for a public grants or loans. Conversely, the amount of R&D tax credits is known only ex-post. In fact, firms first undertake R&D projects and, then, have to document the eligible expenses in order to claim for tax credits. As stressed by Busom et al. (2016, page 6) "when the tax incentive is designed as a deduction from the firm's corporate tax liability, only firms with positive taxable income and

[4] The database was collected within the EFIGE project (European Firms in a Global Economy: internal policies for external competitiveness) supported by the Directorate General Research of the European Commission through its 7th Framework Programme and coordinated by Bruegel. The original sample was identified along three dimensions of stratification: industries (11 NACE-CLIO industry codes), regions (at the NUTS-1 level of aggregation) and size class (10-19; 20-49; 50-249; more than 249 employees). The survey was conducted in 2010.

[5] The specific question of the survey is: "Which percentage of the total turnover has the firm invested in R&D on average in the last three years (2007-2009)?" We excluded 55 companies that report anomalous or unreliable R&D intensity ratios exceeding 50% of total turnover. Albeit young technology-intensive firms may have a higher ratio, in our case, 50 out of 55 firms were more than six years old (and 28 companies were aged twenty and more).

ability to finance - with own or with external funds - their R&D investment will be able to claim it [...]. Firms that lack internal or external funding to start valuable R&D projects are unlikely to benefit from this scheme". In other words, R&D tax credits and R&D subsidies are policy instruments working through different mechanisms and, in the literature, are evaluated with different procedures. First, R&D subsidies are targeted to raise private marginal returns to R&D while tax incentives reduce the cost of doing research (David et al. 2000; Hall and Van Reenen, 2000). Second, whilst research subsidies are granted after a competitive selection of the projects, tax incentives are automatic and hence do not alter the firms' choice about R&D projects, avoiding thus the bias associated with the selection procedure by public agencies. As a consequence, the econometric issues involved in testing the additionality of R&D subsidies are remarkably different from those concerned with tax credits (see in Becker, 2015; Castellacci and Mee Lie, 2015).

TABLE 3 ABOUT HERE

As shown in Table 3, the number of subsidized firms identified following this criterion - and representing the "treated" units in our policy evaluation - is not particularly high[6] and might signal that a non-negligible number of companies under-reported R&D subsidies[7]. Notice that we exclude from our analysis those firms declaring to have benefited from public support but did not report the amounts of public funds. These companies can be neither included into the group of subsidized firms nor among the control group, as they might have exploited R&D tax incentives or, alternatively, did get R&D grants without reporting the amount received. In summary, we consider as "untreated" units those firms that did not benefit from any kind of public support. For those companies reporting the share of R&D financed with public funds, we assume that this amount corresponds to public subsidy to R&D[8]. The intensity of "privately-funded" R&D on total sales is computed subtracting public grants to R&D from the total amount of research expenditures.

[6] In fact, the proportion of subsidized units on R&D-doing firms is lower than arising in previous studies. This share is of 21% in the sample of Spanish firms examined by González and Pazó (2008) over the 1990s,. and of 8.7% among the sample of German companies assessed by Hud and Hussinger (2015) between 2007 and 2010. In France, the proportion of subsidized companies analyzed by Duguet (2004) varies from 26 to 34% between 1990-1997. In Italy, the share of publicly supported firms Carboni 2011) over the years 2001-2003.

[7] To dispel doubts about how the possible under-representativeness of treated firms may affect our findings, we perform a robustness check in Section 4.1.

[8] It should be stressed that the public funds for R&D could include not only direct subsidies or grants but also soft-loans and, to a lower extent, capital loans. However, soft-loans can be assimilated to subsidies because, along with having below-market rates of interest, they may not have to be paid back (for instance, when the funded research project fails from a commercial point of view). On the other hand, as far as public loans had to be repaid, it is doubtful whether they are considered by firms as "public funds" or "bank loans".

Table 3 illustrates that subsidized firms declared, on average, a similar percentage of public grants on total R&D outlays across the EU. In the UK this share is below 30%, while in all the other countries under examination it varies from 34 to 36%. These figures reflect the fact that all the EU countries have to comply with common rules on state- and region-level aids to private R&D. According to the Commission Regulation No. 800/2008 of 6 August 2008, the aids or subsidies for private R&D compatible with the functioning of the common market cannot exceed 50% of companies' project costs for industrial research (60-70% for SMEs) and 25% for experimental development (35-45% for SMEs).

3.1 Characteristics of R&D performing firms

Table 4 details the large set of firm characteristics that we account for in predicting both the propensity to obtain R&D subsidies and the intensity of R&D engagement.

A key attention is paid to the financial conditions of the firm as they may have considerably influenced the effectiveness of R&D subsidies, given that access to external finance became harsher in the aftermath of the crisis (Hall et al., 2016). We control for the financial structure of the company looking at whether it mainly rests on bank credit as a mean to finance its activities.

TABLE 4 ABOUT HERE

Further, we control for whether firm performance changes with age (Czarnitzki and Lopes Bento, 2013); specifically, we include a dummy variable for those companies with more than 20 years from establishment, that we label as old aged firms[9]. To account for firm size, we use two dummy variables: one for medium-sized firms (i.e. those having between 50 and 249 employees) and a second one for large-sized firms (with 250 and more employees). Group affiliation is differentiated according to the nationality of the headquarters (domestic or foreign). Generally, affiliated firms have more funds to engage in R&D and those belonging to domestic groups should have greater capacities to route the procedure for obtaining public support (González et al., 2005). However, the affiliation to foreign groups could reduce the probability of receiving R&D subsidies (Busom, 2000; Hussinger, 2008; Hud and Hussinger, 2015). We also look at whether companies are direct exporter (i.e. whether they sell abroad their products directly from the home country in 2009) or have been awarded with a certification for the quality of their products or processes. Moreover, we discriminate firms for the nature of their management, using a dummy variable for those run by individual holders. These firms

[9] EFIGE classifies firm age into three classes: 0-5 years, 6-20 years, and more than 20 years.

have been found to better evaluate risks and returns to innovation, avoiding the misalignment of incentives between managers and owners (Driver and Guedes, 2012; Honoré et al., 2015).

Another crucial condition that may explain variation across firms in the request for R&D public support is whether the firm did apply for patent protection during the period under exam. Patenting is a very long and complex process, which is characterized by a wide time lag between the conduct of innovative activities and the achievement of outcomes (so-called "gestation lag"), and then between the arrival of inventions and when the firm decides to route the patenting procedure (so-called "application lag"; see Pakes and Schankerman 1984). In this respect, firms indicating that they did apply for patent protection during the survey period (i.e. 2007-09) were probably engaged in R&D activities before 2007. Hence, the status of patent applicant could capture the pre-sample characteristics of R&D performing firms (see Hussinger 2008).

Along with managerial and financial resources, a further key factor influencing R&D engagement is the firm availability of a highly educated workforce, here measured with the share of graduated employees. A high level of human capital is very likely to increase the intensity of R&D expenses as well as the probability to be publicly supported. In fact, companies endowed with a highly educated workforce are better informed about the procedures to participate to public programmes. Moreover, public agencies may consider firms with a highly educated workforce worthier to be funded as having more chances to accomplish ambitious and risky research projects (Busom et al., 2016).

We also look at the ability of the company to increase its technological capabilities by exploiting technical change embodied in capital goods, approximated by investment-to-sales ratio (taken as average between 2007 and 2009). Parisi et al. (2006) show that there could be complementarity between R&D engagement and investment in machinery equipment, especially when the former is targeted to develop process innovation.

Finally, we consider a set of contextual variables capturing whether incentives to undertake R&D, or the request for R&D public support, are shaped by the competitive and technological environment in which the company operates. First, we consider a dummy variable identifying those firms acting as price-taker in the market[10]. Second, we adopt a proxy for technology transfers that may occur among firms operating in the same area; this variable is defined as the average TFP level of the firms active in the same NUTS2 region where the company is located (and excluding the value of the reference company)[11]. Third, as the latter variable reflects realized productivity improvements, we also include a proxy for the knowledge pool available at the regional level, measured by the share

[10] Price-taking firms are identified as those stating that the price of their products is fixed by the market.

[11] Firm-level TFP is made available in the EU EFIGE survey and is computed as Solow residual of a Cobb-Douglas output production function, estimated with the semi-parametric procedure proposed by Levinsohn and Petrin (2003).

of R&D employees in public and business sectors. Fourth, to account for the different policies that may be pursued at regional level to increase competitiveness (and hence affect firm R&D performance), we discriminate the EU NUTS2 regions in which firms are located with a dummy indicating whether the region was classified by the European Commission as a "convergence region" over the EU framework programme 2006-2013 (i.e. recording less than 75% of the EU GDP per capita). In addition, all specifications include a set of industry dummies, to control for industry heterogeneity in R&D behaviour[12]. Summary statistics at country level are reported in Table 5.

TABLE 5 ABOUT HERE

4. Testing the hypotheses of full crowding-out and additionality of R&D subsidies

We evaluate the effectiveness of R&D subsidies by considering two outcome variables: a) the total intensity of R&D expenses on turnover of subsidized firms; and b) the intensity of their private R&D expenditures, i.e. net of the received subsidies. Using the former variable we are able to assess whether treated firms reduced their private funds to R&D by an amount equal to, or even greater than, the subsidy received; in other words, we assess the hypothesis of full crowding-out. Using the latter variable we aim at testing the additionality (or crowding-in) hypothesis, i.e. whether the receipt of a subsidy induced treated firms to invest own additional resources in R&D. Both tests are performed by employing either a non-parametric matching method (PSM) or a parametric estimation based on a two-step Heckman selection model.

4.1 PSM estimations

For evaluating the impact of R&D subsidies we first employ the method of propensity score matching (PSM). This procedure matches each firm benefitting from R&D subsidies to one or more non-subsidized firms that are similar for certain observable variables. Firms are matched on the basis of the propensity score $P(\mathbf{Z}_i)$ yielded by estimating a probit regression for the probability of receiving a subsidy to R&D ($S_i = 1$):

$$P(\mathbf{Z}_i) = \Pr(S_i = 1 \mid \mathbf{Z}_i) \quad (1)$$

where $\mathbf{Z}_i$ is a vector of observable firm characteristics (described in the previous section). The PSM procedure compares the difference in the average R&D intensity ($E(\mathrm{RD})$) between treated firms

[12] To preserve confidentiality on firm identity, the EFIGE data base provides industry identifiers in an anonymous form.

(identified by the suffix 1) and untreated firms (indexed by 0) having a similar score, $P(\mathbf{Z}_i)$. This difference represents the Average Treatment Effect on the Treated (ATET). Formally:

$$ATET = E(\mathrm{RD}_{i1} \mid S_i = 1, P(\mathbf{Z}_i) = p_i) - E(\mathrm{RD}_{i0} \mid S_i = 0, P(\mathbf{Z}_i) = p_i) \quad (2)$$

Table 6 reports the results for the probit regression. There are two factors that, mostly and consistently across countries, are significantly and positively correlated with the probability of getting R&D subsidies: whether the firm applied for a patent and relied exclusively on bank credit as a mean of financing.

TABLE 6 ABOUT HERE

The first result indicates that firms continuously involved in innovative activities (as suggested by the presence of patent applications) have a higher propensity to apply for (and obtain) R&D subsidies. Similarly, companies exclusively relying on bank loans are more likely to receive public support to R&D (see Carboni, 2011). These firms have a low capability of getting credit to carry out R&D projects as, contrarily to investment in physical assets, R&D outlays cannot be used as collaterals in credit negotiations. In addition, bank credit-dependent firms probably suffered more the credit crunch at the outset of the financial crisis. The percentage of subsidized firms is higher among large firms only in Spain and France. This could reflect the complex administrative procedures to access R&D grants, which only firms with larger resources and qualified personnel can easily handle. An alternative interpretation is that the national and regional agencies of these countries could have pursued "picking-the-winner" policies by preferably orienting R&D grants to larger firms that more systematically carry out innovative activities.

The percentage of graduated employees is significantly and positively related to the probability of receiving an R&D subsidy in France and the UK, similarly to the firm location in a "convergence region" of Italy. Conversely, in Italy and Germany, companies located in a region populated by highly productive firms have fewer chances to obtain R&D subsidies, probably as benefiting from larger technology transfers. Finally, firm affiliation to industrial groups, regardless of their foreign or domestic nature, reduces the probability to benefit from R&D subsidies in France while in Spain the reverse holds for companies belonging to domestic groups.

As a next step of the analysis, we apply the matching procedure to the propensity scores yielded by the probit estimates shown in Table 6. We adopt the kernel matching procedure which uses the weighted average score of all control group's units. Moreover, we impose a common support, i.e. we exclude treated firms with a propensity score outside the range of scores assigned to control firms[13].

As the left-hand section of Table 7 illustrates, the ATET estimated for the intensity of total R&D expenses (i.e. gross of public subsidies for the supported firms) is positive and statistically significant for all countries, although at a 10% level for the UK. Overall, these results indicate that, in all major EU countries, subsidized firms did not substitute their private funds to R&D with public subsidies. Therefore, the hypothesis of full-crowding out can be rejected.

TABLE 7 ABOUT HERE

Conversely, the right-hand side of Table 7 shows that, when the intensity of private R&D expenditures (net of R&D subsidies) is taken into account, the mean differences between treated and un-treated firms are never statistically significant[14]. These findings indicate that public subsidies did not stimulate the recipient firms to spend (own) additional resources on R&D. Thus, the hypothesis of additionality is rejected. Interestingly, this finding does not vary across countries indicating that, probably as an effect of a common set of general rules, there is homogeneity in the impact of this type of public policies albeit heterogeneity in the schemes specifically adopted at country level.

Commentato [S1]: bisogna dare una speigazione "economica" non procedurale; facciamolo nelle conclusioni

To control for whether the possible under-representativeness of treated firms may affect the results, we perform a robustness check. We replicate the matching procedure by extending the base of treated companies imputing to those firms that did declare to get some public support but did not report the amount of the grant received (and hence thus far excluded), the average value of the subsidies obtained by the corresponding category of treated companies which is identified on the basis of the size class (small and medium-sized firms). This sensitivity test is performed only for Germany, which is the unique country of our sample that does not dispense fiscal incentives to R&D. For this country, we can safely attribute the average amount of R&D grant without incurring in the risk of imputing subsidies to firms that in reality did benefit from fiscal incentives. By extending in this respect the group of treated firms, we obtain PSM results broadly similar to those reported in Table 7 (see Appendix 2 for details).

[13] We also perform a 1 Nearest Neighbour matching procedure which yields results similar to the kernel one. However, the latter is characterized by a higher quality of the matching. Table A.1 in the Appendix reports three covariate imbalance tests for kernel estimators. For all countries, the mean bias is remarkably lower after matching and the pseudo-R^2 decreases substantially almost approaching zero. At the same time, the LR test shows that there are no systematic observable differences between subsidized and unsupported firms after the matching. The same conclusion emerges by testing for each country, the significance of the mean differences of each observable characteristic (results available upon request).

[14] Being a local procedure of analysis, PSM does not require the use of sampling weights (cf. Caliendo and Kopeinig, 2008, pp. 49-50) In any case, we re-calculated the ATET using the weights of the EFIGE survey attached to the treated firms and found non-remarkable differences from the estimates of Table 7 for all countries but France. For the latter country the weighted value of ATET for total R&D is much higher (4.41) while that for private R&D is positive and significant but only at a 10% level of confidence.

4.2 Parametric estimations

To account for the possible endogenous selection due to unobservable firm characteristics, we employ a two-step Heckman selection model (see Busom, 2000, Hussinger, 2008) composed by a linear R&D intensity equation and a selection equation for the receipt of R&D subsidies (i.e. a probit equation for the potentially endogenous treatment variable). Formally:

$$\begin{aligned} \mathrm{RD}_i &= \mathbf{X}_i'\boldsymbol{\beta} + S_i\gamma + \epsilon_i \\ S_i &= \mathbf{1}(\mathbf{Z}_i'\boldsymbol{\alpha} + u_i > 0) \end{aligned} \tag{3}$$

where the effect of policy support is measured by the parameter γ and the error terms ϵ_i and u_i are jointly normally distributed with zero means and correlation ρ. Non-random selection into treatment may be due to unobserved factors affecting both the treatment and the outcome variable and would result in a significant correlation between the disturbance terms of the two equations[15]. The two-step Heckman (1978) approach restores a zero conditional mean in the R&D intensity equation by including an estimate of the selection bias (the inverse Mills' ratio) that depends only on known parameters of the selection equation (Hussinger, 2008):

Commentato [S2]: dimensione diversa del carattere

$$\mathrm{RD}_i = \mathbf{X}_i'\boldsymbol{\beta} + S_i\gamma + \lambda_{i,tr}\theta_1 + \lambda_{i,ntr}\theta_2 + \epsilon_i\,. \tag{4}$$

Under normality of error terms, $\lambda_{i,tr} = [\phi(\mathbf{Z}_i'\boldsymbol{\alpha})]/[\Phi(\mathbf{Z}_i'\boldsymbol{\alpha})]$ and $\lambda_{i,ntr} = -[\phi(\mathbf{Z}_i'\boldsymbol{\alpha})]/[1-\Phi(\mathbf{Z}_i'\boldsymbol{\alpha})]$ reflect the hazard rates of treated and non-treated firms yielded from the probit regression. In the light of the non-random (generated) nature of these additional regressors, Eq. (4) is estimated bootstrapping standard errors with 500 replications. Notice, also, that to preserve the generality of results, parametric estimates are obtained with sampling weights which reflect the share of each category of companies in national samples.[16]

Despite the parameters of model (4) are theoretically identified even when the same set of regressors enters the equations for RD_i and S_i (i.e. $\mathbf{X}_i$ and $\mathbf{Z}_i$ include the same variables), to improve identification it is a standard practice to include additional covariates in the probit equation of the potentially endogenous treatment variable S_i. These variables are assumed to affect the probability of being publicly supported, and not to have any direct impact on the outcome variable (and therefore can be excluded from the R&D intensity equation).

[15] Another econometric issue is the potential bias associated with the fact the treatment variable is observed only for R&D active firms, and this may exacerbate the impact estimated for this variable on R&D intensity. For each country, we test for this possibility by running a Heckman sample-selection regression for the probability of doing R&D and for the R&D intensity equation, finding evidence against the presence of self-selection. For sake of brevity, these auxiliary results are not reported but are available on request.

[16] In the EFIGE survey, relative weights are computed for each country according to the firms' size and industry.

For the aim of our analysis, we opt for using variables reflecting differences in some institutional and structural characteristics of the administrative areas in which the firms are located. The set of identification variables which are used as restriction conditions includes; an index reflecting the institutional quality of the region; the net migration rate; the aging index; the degree of accessibility; the percentage of firms having Internet access (see Table 8 for details).

TABLE 8 ABOUT HERE

The rationale behind the use of such variables is that the less dynamic and attractive the region (i.e. with a negative net immigration rate, a high aging rate and poor physical and digital infrastructures), the higher is the probability for a firm to apply for and receive some public support to R&D. Other things being equal, firms located in regions with a high quality institutional setting are more likely to search for and obtain public provisions to R&D. The spirit of this identification strategy follows Einiö (2014) who predicts the probability of Finnish firms to participate to R&D support programmes by exploiting variation in regional characteristics. As discussed above, the identification variables used in the probit model have to be uncorrelated with R&D intensity. We assess this assumption including these regressors into the outcome equation finding that R&D intensity is always independent on such additional covariates (un-reported but available upon request).

TABLE 9 ABOUT HERE

Table 9 shows estimates for the probability to receive public support to R&D including regional identification variables. These represent the first step of the Heckman regression described above. Overlooking probit results that have been discussed earlier, it should be pointed out that, for each country, at least one regional identification variable is found to significantly influence the probability of benefiting from R&D public grants.

TABLE 10 ABOUT HERE

Parametric estimates resulting from the second step of the Heckman model are reported in Table 10. Both estimates on total and private R&D intensities include the selection hazard terms (i.e., inverse Mills' ratios) estimated from the probit model. The selection correction terms for un-treated firms are significantly different from zero only for Germany (total and private R&D intensity) and France (total R&D intensity only). Thus, for most of our estimations, the condition of the firm to be publicly funded is unrelated to unobservable selection factors. In fact, except for these two countries, the Heckman two-step model provides estimates for the receipt of R&D subsidies consistent with those yielded by an OLS model that considers the treatment variable as exogenous. Coherently with the PSM results, public support to R&D did neither induce firms to replace their own funds with public grants nor increase the amount of their resources allocated to research projects in all countries. In other words, both hypotheses of full crowding-out and additionality of R&D subsidies can be rejected also on the basis of parametric estimates. In term of parameter sizes, structural estimates fall close to the values of the ATET yielded by the matching procedure, especially for France and Germany concerning total R&D intensity. As in the PSM analysis the impact of public support is found to be positive but significant at a 10% level of confidence for the UK (cf. Table 7).

5. Discussion and concluding remarks

This paper has assessed the counter-cyclical effects of public subsidies to business R&D implemented in Europe during the crisis of the late 2000s. Exploiting unique firm-level information collected from a survey conducted in the largest EU countries (France, Germany, Italy, Spain and the UK) in the aftermath of the crisis, we have performed a micro-econometric evaluation of the effectiveness of R&D public subsidies granted between 2007 and 2009. We have used two main methods of analysis - PSM and parametric estimation - that accounted for the effect of observable characteristics, non-observable factors and selectivity issues.

Taken together, both PSM and parametric estimates suggest that EU manufacturing firms benefiting from research subsidies did not reduce the intensity of their total R&D expenditures on turnover over the period 2007-2009 but, by exploiting public grants, continued without breaks research activities maintaining their innovative capability. These findings are in line with micro-econometric studies surveyed in Section 2 which, overall, provide evidence against the hypothesis that R&D subsidies fully crowd-out private funds for research.

According to our estimates, subsidized firms were not able to increase their own research efforts and, on average, their intensity of R&D expenses (net of subsidies) did not differ from un-supported companies. As discussed in Section 2, there are few similar studies testing the hypothesis of additionality of R&D subsidies. González and Pazó (2008) found a result consistent with our estimates for a sample of Spanish firms observed from 1990 to 1999. On the contrary, Duguet (2004) and Carboni (2011) provide evidence supporting the additionality hypothesis for a sample of French and Italian firms respectively observed before the great crisis. Similarly, Hussinger (2008) estimates that, in Germany, €1 of R&D subsidies increased private R&D spending by €1 on average between 1990 and 2000.

One possible explanation for the discrepancy between our findings and those provided in earlier studies is the different time periods covered . While previous analyses mostly look at the 1990s and, at best, the early 2000s, our data cover the period between 2007 and 2009, which was characterized by the financial turmoil (2008) and, subsequently, by a severe downturn (2009). Probably, in response to the crisis, subsidized firms cut or postponed some of their investment plans, in proportion to their turnover decrease. Thus, contrary to what occurred in earlier years, these companies did not invest additional own resources in R&D but allocated these funds to other less risky activities.

Our findings are fully consistent with the evidence provided by Hud and Hussinger (2015) on a sample of German SMEs observed between 2006 and 2010. These authors find that the intensity of private R&D expenditures (net of public subsidies) of subsidized firms was always systematically higher than for un-supported companies apart from 2009. It is shown that the latter result is not due to the remarkable expansion of the subsidy program in 2009 (cf. Brautzsch et al., 2015), which could have induced more SMEs to exploit public grants for the time being, but rather to a generalised reluctance to undertake investment activities (including R&D) during the crisis' peak. In essence, the lack of additionality of direct funds to R&D on private research intensity "lasted only for one year after which SMEs recovered from the first shock of the crisis and returned to the pre-crisis R&D investment behaviour" (Hud and Hussinger, 2015, p. 1852).

In summary, our analysis suggests that, albeit ineffective to raise private funds for research, public subsidies to R&D were not exploited opportunistically by EU manufacturing firms to reduce their own efforts. Our findings indicate that, in Europe, R&D subsidies had moderate counter-cyclical effects, i.e. they were not expansive but, probably, thwarted the reduction of business R&D that would have been registered if these funds had not been granted to manufacturing firms.

As concluding remark, it must be acknowledged that our analysis provides only a partial outlook on the effectiveness of R&D policies. First of all, R&D subsidies may not have been particularly expansive during the crisis as most EU governments sustained firms' innovative activities through other policy instruments. In fact, along with public grants, in all the examined countries but Germany, governments also provided tax incentives to private companies performing R&D which, in some cases, were used more intensively than R&D subsidies (see OECD, 2012). Moreover, a fully comprehensive assessment of R&D subsidies should cover the entire business cycle (i.e. the downturn and the recovery) while here data availability forced us to consider only the earlier phase of crisis.

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Table 1: Firm-level studies on the impact of R&D subsidies in the countries covered by the present paper

	Country	Outcome variable: R&D expenses or intensity on sales	Method	Results
Almus and Czarnitzki (2003)	Germany (East)	Total	Matching	Full crowding-out rejected
Czarnitzki and Licht (2006)	Germany (East)	Total	Matching	Full crowding-out rejected
Aleke et al. (2011)	Germany (East)	Total	Matching	Full crowding-out rejected
Hussinger (2008)	Germany	Private	Selection model	Additionality
Hud and Hussinger (2015)	Germany	Private	Matching	Additionaliy
Busom (2000)	Spain	Total	Selection model	Full crowding-out rejected
Gonzalez et al. (2005)	Spain	Private	IV	Full crowding-out rejected
González and Pazó (2008)	Spain	Private	Matching	Full crowding-out rejected
Duguet (2004)	France	Private	Matching	Additionality
Carboni (2011)	Italy	Private	Matching	Additionality
Barbieri et al. (2012)	Italy	Total	DID	Full crowding-out rejected
Cerulli and Potì (2012a)	Italy	Total	Matching	Full crowding-out rejected
Cerulli and Potì (2012b)	Itay	Total	Matching Selection Model DID	Full crowding-out rejected

Table 2: Annual rates of change of business R&D*

	2006	2007	2008	2009	2010	2011
EU28	5.49	3.52	3.70	-2.10	1.90	6.08
Germany	6.14	2.84	6.17	-3.43	2.87	7.69
Spain	14.98	10.00	6.05	-6.50	-0.97	-1.55
France	4.01	0.93	1.66	2.48	2.78	4.10
Italy	2.56	12.42	5.00	-1.30	3.00	0.84
UK	4.68	6.21	-1.17	-3.62	-0.32	6.08

* R&D originally expressed in millions of euros at constant prices (2010). Source: own computation from Eurostat data

Table 3: Firms performing R&D and benefiting from R&D subsidies by country

	France	Germany	Italy	Spain	UK
Firms performing R&D	1488	1539	1644	1195	1040
Firms benefiting from R&D support (subsidies and/or tax incentives)	550	268	568	495	292
Firms reporting R&D subsidies (*treated*)	139	87	89	147	36
Firms without any R&D support (*untreated*)	938	1271	1076	700	748
Share of subsidized firms on R&D performers	9.34	5.75	5.41	12.3	3.46
Share of subsidies on the R&D of subsidized firms	36.22	34.17	36.49	34.92	29.72

Source: own computation from the EFIGE data base

Table 4: Observable characteristics of R&D performing firms*

Label	Type	Description
R&D subsidies	dummy	Equal to 1 for firms benefiting from R&D subsidies, 0 otherwise
Gross R&D intensity	percentage	Total R&D expenditure over sales
Net R&D intensity	percentage	R&D expenditure less public grant to R&D over sales
Old age	dummy	Equal to 1 for firms with more than 20 years from establishment; 0 otherwise
Medium-sized	dummy	Equal to 1 for firms with employees between 50 and 249; 0 otherwise
Large-sized	dummy	Equal to 1 for firms with 250 employees and over; 0 otherwise
Individual holder	dummy	Equal to 1 if the firm is managed by an individual holder;
Quality certification	dummy	Equal to 1 if the firm has a quality certification; 0 otherwise
Foreign group	dummy	Equal to 1 if the firm belongs to a foreign group; 0 otherwise
National group	dummy	Equal to 1 if the firms belongs to a national group; 0 otherwise
Investment/sales	percentage	Investment/total sales
Exporter	dummy	Equal to 1 if the firm is a direct exporter ; 0 otherwise
Graduated employees	percentage	Share of university graduates on total employees
Patent	dummy	Equal to 1 for firms having applied for patent protection 0 otherwise
Bank credit	dummy	Equal to 1 if the firm relies on bank loans to finance their activity; 0 otherwise
Price taker	dummy	Equal to 1 if firm's prices that are fixed by the market; 0 otherwise
Regional R&D intensity	percentage	Regional R&D personnel on total employees
Regional TFP	level	Average TFP level of the firms located in the same region
Convergence region	dummy	Equal to 1 for firms located in NUTS2 regions classified as "convergence regions" for the period 2006-2013 (i.e. with less than 75% of the EU GDP per capita in 2004); 0 otherwise **
Industries	dummies	Randomized EFIGE industry identifiers

*Source: EFIGE data base. **Source= European Commission.

Table 5: Summary statistics*

Label	Variable	France	Germany	Italy	Spain	UK
R&D subsidies	dummy	0.13	0.06	0.08	0.17	0.05
Gross R&D intensity	percentage	5.22	7.21	6.43	7.06	5.34
Net R&D intensity	percentage	4.83	6.88	6.15	6.43	5.16
Old age	dummy	0.69	0.65	0.64	0.56	0.59
Medium-sized	dummy	0.23	0.32	0.16	0.16	0.29
Large-sized	dummy	0.08	0.15	0.05	0.05	0.06
Individual holder	dummy	0.64	0.78	0.77	0.69	0.77
Quality certification	dummy	0.55	0.73	0.61	0.67	0.69
Foreign group	dummy	0.24	0.11	0.16	0.14	0.13
National group	dummy	0.13	0.08	0.05	0.05	0.18
Investment/sales	percentage	8.59	11.4	9.61	14.5	8.96
Exporter	dummy	0.74	0.81	0.83	0.76	0.78
Graduated employees	percentage	1.65	6.73	1.29	3.38	4.43
Patent	dummy	0.17	0.25	0.19	0.17	0.20
Bank credit	dummy	0.36	0.23	0.59	0.68	0.31
Price taker	dummy	0.43	0.40	0.34	0.25	0.31
Regional R&D intensity	percentage	1.35	1.41	0.98	1.08	1.16
Regional TFP	numeric	1.03	1.28	0.85	0.91	0.95
Convergence region**	dummy	0.00	0.14	0.09	0.25	0.05

*Source: EFIGE data base. **Source= European Commission.

Table 6: Probit regression for the receipt of R&D subsidies

	France	Germany	Italy	Spain	UK
Old age	-0.0533	-0.296**	0.0814	0.123	0.290
	(0.122)	(0.139)	(0.128)	(0.117)	(0.200)
Medium-sized	-0.0279	0.158	0.237	0.526***	-0.0926
	(0.143)	(0.140)	(0.159)	(0.150)	(0.209)
Large-sized	0.431**	-0.169	0.138	1.262***	
	(0.209)	(0.226)	(0.274)	(0.262)	
Individual holder	-0.353***	0.007	-0.148	-0.156	-0.115
	(0.123)	(0.180)	(0.179)	(0.132)	(0.249)
Quality certification	0.117	-0.0891	0.0440	0.207	-0.0338
	(0.118)	(0.144)	(0.135)	(0.131)	(0.216)
Foreign group	-0.504**	-0.528*	-0.0895	-0.482	-0.594*
	(0.199)	(0.317)	(0.326)	(0.320)	(0.321)
National group	-0.312**	-0.118	-0.0377	0.429***	-0.0482
	(0.149)	(0.222)	(0.195)	(0.164)	(0.286)
Investment/Sales (%)	0.003	0.008*	0.007	0.001	-0.009
	(0.004)	(0.004)	(0.005)	(0.004)	(0.010)
Exporter	0.472***	0.192	0.112	0.189	0.172
	(0.150)	(0.177)	(0.176)	(0.150)	(0.276)
Graduated employees	0.013**	-0.005	0.001	0.003	0.016***
	(0.006)	(0.005)	(0.008)	(0.005)	(0.006)
Patent	0.745***	0.501***	0.527***	0.510***	0.964***
	(0.127)	(0.136)	(0.136)	(0.140)	(0.210)
Bank credit	0.504***	0.194	0.471***	0.500***	0.428**
	(0.111)	(0.135)	(0.133)	(0.133)	(0.194)
Price taker	0.109	0.0678	0.166	0.181	0.115
	(0.110)	(0.126)	(0.122)	(0.130)	(0.195)
Regional R&D intensity (%)	0.223**	0.0146	0.549	-0.0660	-0.222
	(0.0961)	(0.136)	(0.353)	(0.208)	(0.408)
Regional TFP	-0.726	-3.084***	-1.330***	-0.478	-0.865
	(0.443)	(0.683)	(0.413)	(0.387)	(0.867)
Convergence region		0.258	0.539***	-0.203	0.636*
		(0.196)	(0.204)	(0.163)	(0.340)
Constant	-1.863***	-1.056***	-2.968***	-1.742***	-1.934***
	(0.284)	(0.369)	(0.514)	(0.375)	(0.698)
Observations	1,077	1,358	1,165	847	717
Log-likelihood	-343.53	-258.55	-275.51	-319.69	-113.94

°Industry effects are not reported. *** p<0.01, ** p<0.05, *p<0.10

Table 7: Share of total and private R&D expenditures on total sales: mean differences after the kernel matching°

	Total R&D intensity			Private R&D intensity		
	Subsidized Firms	Unsupported firms	ATET	Subsidized Firms	Unsupported firms	ATET
France (n=132)	8.197	5.270	2.927***	5.269	5.270	-0.001
Germany (n=86)	10.116	6.904	3.213***	6.610	6.904	-0.294
Italy (n=88)	8.648	6.397	2.250**	5.305	6.397	-1.092
Spain (n=145)	8.324	5.774	2.551**	5.447	5.774	-0.327
UK (n=35)	8.486	6.308	2.178*	6.082	6.308	-0.226

° Applied with the imposition of common support. In brackets, n identifies the number of matched firms. ***p<0.01; **p<0.05

Table 8: Regional identification variables

Label	Type	Description	Source
Migration rate	Continuous	Net migration rate/population (2001-05)	Espon
Aging index	Continuous	Ratio between population aged 65 yrs and over and population under 14, mean 2007-09	Espon
Institutional quality	Categorical	Quality of regional governance (survey on citizens' satisfaction of regional services), 2009-2010	Charron et al. (2011)
Accessibility	Continuous	Multi-modal potential accessibility, standardized index (EU average= 100), 2006	Espon
Internet access	Continuous	Percentage of firms having internet access	Espon

Table 9: Probit regression for the receipt of R&D subsidies with identification variables

	France	Germany	Italy	Spain	UK
Old age	-0.0588	-0.327**	0.0698	0.196	0.231
	(0.122)	(0.143)	(0.126)	(0.122)	(0.181)
Medium-sized	-0.00561	0.170	0.248	0.476***	-0.143
	(0.145)	(0.151)	(0.151)	(0.148)	(0.207)
Large-sized	0.461**	-0.0782	0.285	1.335***	
	(0.210)	(0.244)	(0.243)	(0.271)	
Individual holder	-0.361***	0.0215	-0.146	-0.0764	-0.0990
	(0.124)	(0.212)	(0.170)	(0.132)	(0.260)
Quality certification	0.123	-0.0378	0.0499	0.227	-0.0500
	(0.118)	(0.146)	(0.136)	(0.144)	(0.212)
Foreign group	-0.518***	-0.517	-0.308	-0.642**	-0.502
	(0.199)	(0.418)	(0.294)	(0.286)	(0.371)
National group	-0.327**	-0.0715	-0.0353	0.433***	0.0123
	(0.150)	(0.282)	(0.194)	(0.166)	(0.267)
Investment/Sales (%)	0.0333**	0.00607	0.00708	0.00148	-0.00891
	(0.0140)	(0.00400)	(0.00483)	(0.00376)	(0.00843)
Exporter	0.485***	0.243	0.137	0.178	0.135
	(0.151)	(0.167)	(0.175)	(0.166)	(0.253)
Graduated employees	0.0132**	-0.00732*	-0.000164	0.00152	0.0139**
	(0.00584)	(0.00442)	(0.00861)	(0.00551)	(0.00559)
Patent	0.749***	0.585***	0.493***	0.480***	1.019***
	(0.128)	(0.139)	(0.136)	(0.151)	(0.192)
Bank credit	0.510***	0.235*	0.432***	0.413***	0.468**
	(0.111)	(0.139)	(0.138)	(0.146)	(0.188)
Price taker	0.111	0.0715	0.147	0.179	0.156
	(0.110)	(0.121)	(0.124)	(0.132)	(0.190)
Regional R&D intensity (%)	0.239**	0.219	0.598	0.477	0.00213
	(0.100)	(0.155)	(0.408)	(0.335)	(0.396)
Regional TFP	-0.771*	-2.681***	-1.556***	-0.441	0.00890
	(0.456)	(0.781)	(0.413)	(0.410)	(1.027)
Convergence region		-0.0575	1.183***	-0.321*	0.220
		(0.253)	(0.357)	(0.174)	(0.287)
Identification variables					
Aging index		0.729*			
		(0.403)			
Institutional quality	0.295		0.476**		
	(0.355)		(0.214)		
Internet access				-0.0569***	
				(0.0220)	
Institutional quality x Investment/Sales (%)	-0.0565**				
	(0.0268)				
Accessibility					-1.285*
					(0.759)
Net migration rate					-0.793**
					(0.394)
Constant	-2.065***	-2.628***	-2.799***	-0.270	4.237
	(0.340)	(0.945)	(0.576)	(0.651)	(3.467)
Observations	1,077	1,358	1,165	847	717
Log-likelihood	-352.7	-257.95	-268.95	-315.01	-115.76

°Industry effects are not reported. Sampling weights used. *** p<0.01, ** p<0.05, *p<0.10

Table 10: Heckman estimation of R&D intensity

	Total R&D intensity					Private R&D intensity				
	France	Germany	Italy	Spain	UK	France	Germany	Italy	Spain	UK
R&D subsidy (ATET)	2.953***	3.380***	2.514***	2.805***	2.040*	0.0509	-0.201	-0.935	-0.409	-0.141
	(0.682)	(1.038)	(0.931)	(0.858)	(1.094)	(0.541)	(0.721)	(0.745)	(0.785)	(1.012)
Old age	-1.507***	-0.0792	-0.204	0.00383	1.199**	-1.271***	0.297	-0.260	0.0366	1.217**
	(0.429)	(0.837)	(0.433)	(0.672)	(0.483)	(0.415)	(0.787)	(0.434)	(0.667)	(0.478)
Medium-sized	-1.584***	-1.280**	-0.695	-0.975	-2.309***	-1.374***	-1.243**	-0.306	-0.664	-2.205***
	(0.361)	(0.507)	(0.584)	(0.848)	(0.525)	(0.337)	(0.486)	(0.577)	(0.825)	(0.528)
Large-sized	-0.821	0.00475	-1.989**	0.706		-0.0737	0.183	-1.733**	1.291	
	(1.053)	(0.595)	(0.927)	(2.091)		(0.971)	(0.576)	(0.840)	(1.979)	
Individual holder	0.503	-0.0356	1.152*	-0.0221	0.442	0.648	0.145	0.831	-0.256	0.434
	(0.724)	(0.594)	(0.622)	(0.775)	(0.684)	(0.690)	(0.562)	(0.621)	(0.771)	(0.680)
Quality certification	0.902*	0.106	0.798*	-0.132	0.598	0.809*	0.152	0.742*	-0.129	0.655
	(0.472)	(0.414)	(0.433)	(0.706)	(0.511)	(0.448)	(0.383)	(0.426)	(0.699)	(0.507)
Foreign group	-0.524	-0.447	2.349*	-2.450	-0.592	-0.647	0.236	2.056	-2.274	-0.730
	(1.053)	(1.233)	(1.392)	(1.553)	(0.947)	(0.989)	(1.167)	(1.400)	(1.569)	(0.964)
National group	-0.747	-0.342	0.739	-1.177	-0.0860	-0.791	0.0520	0.501	-0.738	-0.0419
	(0.680)	(0.693)	(0.674)	(0.910)	(0.627)	(0.645)	(0.686)	(0.680)	(0.865)	(0.618)
Investment/Sales (%)	0.0464**	0.127***	0.140***	0.183***	0.0713***	0.0441**	0.112***	0.146***	0.166***	0.0648***
	(0.0192)	(0.0290)	(0.0263)	(0.0230)	(0.0252)	(0.0181)	(0.0269)	(0.0262)	(0.0240)	(0.0247)
Exporter	1.108	0.224	0.777	-0.109	0.976*	1.094	-0.194	0.728	-0.150	0.988*
	(0.874)	(0.582)	(0.528)	(0.697)	(0.541)	(0.821)	(0.554)	(0.522)	(0.659)	(0.546)
Graduated employees	0.00485	0.152***	-0.0452	0.0585*	0.0422*	0.00281	0.157***	-0.0448	0.0492	0.0418*
	(0.0417)	(0.0240)	(0.0370)	(0.0314)	(0.0255)	(0.0381)	(0.0238)	(0.0372)	(0.0303)	(0.0246)
Patent	2.020	-0.494	1.525**	4.351***	2.207*	1.950	-0.948	1.883**	3.847***	2.234*
	(1.386)	(1.049)	(0.772)	(1.327)	(1.251)	(1.311)	(1.005)	(0.753)	(1.331)	(1.246)
Bank credit	0.341	-1.185**	0.997	0.187	-0.211	0.368	-1.253**	1.223**	0.178	-0.144
	(0.915)	(0.580)	(0.627)	(0.804)	(0.771)	(0.862)	(0.550)	(0.617)	(0.785)	(0.774)
Price taker	-0.578	-1.477***	-0.327	-0.841	0.239	-0.417	-1.325***	-0.106	-0.654	0.274
	(0.407)	(0.399)	(0.435)	(0.570)	(0.472)	(0.382)	(0.381)	(0.433)	(0.532)	(0.475)
Regional R&D int. (%)	0.836*	0.492	0.708	0.408	-1.364	0.784*	0.370	1.124	0.685	-1.155
	(0.495)	(0.390)	(1.146)	(0.799)	(0.832)	(0.470)	(0.359)	(1.130)	(0.789)	(0.834)
Regional TFP	-0.556	9.904	-1.850	-0.0365	3.399	-0.0792	11.52*	-2.853	-0.460	2.304
	(1.936)	(6.410)	(2.047)	(1.963)	(2.261)	(1.848)	(6.161)	(2.030)	(1.905)	(2.256)
Inverse Mills' ratio treated	3.275	-2.821	3.730*	1.067	1.277	2.639	-3.668*	4.217**	0.680	1.609
	(2.153)	(2.040)	(2.027)	(1.857)	(1.516)	(2.002)	(1.943)	(1.979)	(1.926)	(1.531)
Inverse Mills' ratio un-treated	-7.735*	4.379	-4.442	3.406	-3.659	-5.641	5.307*	-4.163	3.945	-4.054
	(4.202)	(3.167)	(7.208)	(2.627)	(5.121)	(3.875)	(2.709)	(7.110)	(2.650)	(5.042)
Constant	-4.076	8.769**	-6.879	3.835	0.310	-2.643	10.55***	-8.488	4.549	-0.798
	(5.338)	(3.603)	(5.707)	(4.449)	(3.790)	(4.954)	(3.363)	(5.596)	(4.528)	(3.834)
Observations	1,077	1,358	1,165	847	717	1,077	1,358	1,165	847	717
R-squared	0.186	0.218	0.082	0.225	0.120	0.115	0.207	0.075	0.192	0.105

°Industry effects are not reported. Sampling weights used. Bootstrapped standard errors with 500 replications. *** p<0.01, ** p<0.05, *p<0.10

Appendix 1

Table A.1: Covariate imbalance testing for kernel matching with the imposition of common support

	France		Germany		Italy		Spain		UK	
	Before matching	After	Before matching	After	Before matching	After	Before matching	After	Before matching	After
Pseudo R^2	0.155	0.006	0.176	0.009	0.103	0.004	0.165	0.013	0.176	0.014
LR test (p value)	0.000	1.000	0.000	1.000	0.000	1.000	0.000	0.993	0.000	1.000
Mean bias	22.4	4.5	27.2	4.6	20.6	3.8	25.2	5.9	25.8	6.4

Appendix 2 - Robustness check for the possible under-representativeness of treated firms

In Section 4.1 we discuss that the number of firms that reported a positive share of public funds among the sources of finance for R&D is not particularly high and hence one may wonder whether our findings are affected by a non-response bias, i.e. a scarce representativeness of treated firms. To exclude this, one can artificially increase the set of subsidized firms by imputing to those that declared to get some public support but did not report the amount of subsidies (and then excluded from the analysis), the average value of the subsidy obtained by the corresponding category of treated companies. Clearly, this tentative analysis cannot be performed for those countries providing both direct subsidies and tax allowances as firms that under-reported R&D granted cannot be distinguished. Hence, this exercise is done only for Germany being the only country in the sample without a scheme of R&D tax incentives. For this country, we assume that firms declaring to have been publicly supported but did not report the amount of public provisions, in percentage, received a subsidy equivalent to the average of the reporting firms within the same size class. Indeed, according to the EU regulation on public aids to private R&D, small firms can benefit from higher shares of public subsidies compared to medium- and large-sized firms (see Section 3).

Table A.2: German publicly supported firms reporting and not reporting R&D subsidies

	Number of firms reporting R&D subsidies	Share of public subsidy on total R&D investment			Number of publicly supported firms not reporting R&D subsidies
		Mean	St. Dev.	Median	
Small firms	48	0.39	0.27	0.40	71
Medium-sized firms	32	0.29	0.20	0.27	82
Large firms	7	0.23	0.18	0.20	28

Table A.2 confirms that the share of public subsidies on total R&D investment decreases with firm size. Because only 7 large firms reported public funds for their R&D activities, it would be ill-advised to impute their average share of public subsidies to the 28 large firms declaring to have been publicly supported without reporting the amount of public provisions. As a consequence, the imputation of R&D subsidies is limited to the German firms of small and medium size (71 and 82, respectively).

Table A.3: Share of total and private R&D expenditures on total sales: mean differences after the kernel matching - German small and medium-sized firms °

	No. of subsidized firms	No. of non subsidized firms	Matched firms	Total R&D intensity of subsidized	Total R&D intensity of non subsidized	ATET
Total R&D Intensity						
Subsidies reported	80	1054	78	10.141	6.413	3.728***
Subsidies reported and imputed	233	1077	232	9.431	6.996	2.435***
Private R&D Intensity						
Subsidies reported	80	1054	78	6.514	6.413	0.101
Subsidies reported and imputed	233	1077	232	6.195	6.996	-0.801

° kernel matching is applied with the imposition of common support. ***p<0.01; **p<0.05

Table A.3 reports the results of the PSM performed with the kernel matching procedure with propensity scores achieved by means of the same probit model applied in Section 4.1. For the intensity of total R&D expenses, the ATET turns out to be positive and statistically significant either when we consider only firms explicitly reporting R&D subsidies (80 observations, 78 matches) or when we also consider companies with the imputation of public provisions (233 companies in total, 222 matches). In the latter case, the size of the ATET is lower, perhaps reflecting the imputation of a subsidy larger than the one actually received. Looking at private R&D intensity (net of public subsidies), the ATET turn out to be always insignificant. Accordingly, the main findings of the present paper (i.e. that both the hypotheses of full-crowding and additionality of R&D subsidies can be rejected) do not seem to be affected by under-representativeness of treated firms.