The effects of public supports on business R&D: firm-level evidence across EU countries

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Abstract

Using homogenous firm-level data for the largest Member States of the EU over the period 2007-2009, we test whether manufacturing firms receiving R&D public supports (mainly subsidies) spent more on R&D. The analysis is performed using both non-parametric techniques and parametric estimation methods accounting for the possible endogeneity of R&D public support. The hypothesis of full crowding-out of private with public funds (i.e. public support reduced privately-funded R&D expenses) is rejected for all countries, with the partial exception of Spain. However, we do not find evidence for the hypothesis of additionality of R&D subsidies (i.e. direct funding did not raise private R&D). These findings contrast with earlier works and might be due to the period under assessment, which covers the financial turmoil and the subsequent economic downturn. Our estimates indicate that, albeit not expansive, public funding to R&D thwarted the reduction of firm R&D effort at the outset of financial crisis.

JEL codes: C21, D04, O32, O38

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

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Part of this research was carried when Francesco Venturini was visiting fellow at the East and Southeast European Studies (IOS), Regensburg (Germany). The author acknowledges the financial support by this institution.

1. Introduction

Due to the nature of R&D investment and its crucial role for economic growth, public policies to foster business R&D have been increasingly adopted world-widely, especially by developed countries. In the latest years, numerous firm-level studies have investigated the effectiveness of these policies, but only a slight majority of such works have documented positive effects on business R&D (see Zùniga-Vicente et al., 2014; Becker, 2014). The ambiguity of results is partly attributable to the large array of policy instruments that can be adopted to promote R&D (subsidies, tax incentives, public procurements, etc.), to the alternative objectives of such policies (increase in R&D investment, patents, productivity of R&D performing firms) and to the fact that different micro-econometric methods have been used for evaluating such measures. Moreover, results do vary because of the different time periods analyzed, the control variables used and, last but not least, the heterogeneity in the quality of the governmental agencies managing such public programmes.

The present paper assesses the effectiveness of R&D policies by using homogenous firm-level data for the largest Member States of the European Union: France, Germany, Italy, Spain and the UK. The comparability across countries of the data used makes our empirical study almost unique[2]. Our aim is of testing whether firms receiving public supports to R&D, mainly direct subsidies, spent more on research. We use novel data for nation-wide representative (cross-sectional) samples of manufacturing firms from a survey (*European Firms in the Global Economy-EU EFIGE* survey) carried out in the aftermath of the financial crisis, covering the period 2007-2009. The database offers numerous information on firm characteristics and on those contextual factors influencing the company's choice of undertaking R&D projects and exploiting public support to perform such activities. This reduces the risk of bias in the regression analysis associated with the cross-sectional nature of the data which, clearly, limits the possibility to account for unobserved firm heterogeneity or control for the persistent engagement of the firm in R&D activities and in the usage of public supports. Another crucial feature of the paper is that of adopting different methods that permit to address the main econometric issues involved in policy evaluation analyses. We first adopt a propensity score matching (PSM) procedure. As public R&D supports are not distributed randomly, this methodology addresses the problem of "selection on observables". However, to account for the potential biases associated with the "selection on unobservables", we also carry out a parametric regression analysis based on a conditional mixed-model system estimated with the maximum likelihood method. The latter procedure addresses the possible simultaneity (endogeneity) between

[2] The only micro-econometric study providing a cross-country comparison of the impact exerted by public subsidies on firm R&D intensities is Czarnitzki and Lopes Bento (2012). In this case, however, the authors use a narrower set of control variables that, although similar, were collected by means of different national surveys. Freitas et al. (2015) perform a panel regression analysis on Norway, France and Italy over the 2000s but they mainly focus on the impact of R&D tax credit.

the firm propensity to invest in R&D and to benefit from R&D public supports. This regression method considers a simultaneous system composed by an equation for R&D performance (i.e. the outcome variable) and an equation for the receipt of a public support (i.e. the treatment variable). The impact of the latter variable is predicted exploiting variation in various structural and institutional characteristics of the regions in which the firms are located. In absence of endogeneity, we estimate parametrically the impact of R&D policy supports by means of OLS. Overall, our analysis is therefore able to overcome the main sources of heterogeneity and the key econometric concerns affecting most empirical works.

We first consider together firms getting direct funding and those exploiting tax incentives. Then, we refine the analysis by restricting the focus on those accessing R&D grants only. In this assessment, we consider two measures of outcome, namely gross and net R&D expenditure on sales, so to check the hypothesis of full or partial crowding-out (i.e. R&D policy did raise gross research intensity) and the hypothesis of crowding-in/additionality (i.e. R&D policy did raise net research intensity). With the only exception of Spain, the hypothesis of full crowding-out is rejected for all countries, irrespective of the estimation technique used. However, public subsidies do not induce firms to spend additional (own) resources on R&D and, therefore, we reject for all countries the hypothesis of additionality of this policy instrument. Our findings indicate that, albeit not expansive, public funding to R&D thwarted the reduction of firm R&D effort at the outset of financial crisis.

The paper is organized as follows. Section 2 briefly reviews the empirical literature, illustrating the nature of R&D public supports adopted by the EU countries under examination. Section 3 describes the variables employed in the analysis. In Section 4 we perform PSM and parametric estimates for the effect of public support on total R&D intensity, without distinguishing between direct subsidies and fiscal incentives. This represents a test for the hypothesis of full crowding-out. In Section 5 we assess the additionality of R&D subsidies by investigating the responsiveness of the intensity of private R&D expenditures (net of public subsidies) to variation in this type of public grants. Finally, Section 6 summarizes the results and concludes.

2. Estimating the impact of public incentives 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. As a result, R&D active firms have to rely mainly upon self-financing.

While the rationale for R&D policies is widely recognized, there is less agreement among economists on their actual effectiveness, due to the ambiguity of the results of empirical analyses. Firstly, 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 outcome in a different extent. In the following, we shall primarily focus on R&D subsidies but we also briefly discuss the effect of tax credits for completeness. With respect to the policy objective, attention will be confined to the increase of R&D effort by private companies.

The main difficulty in evaluating R&D (as well as other) policies is due to presence of selectivity biases. In fact, companies benefiting from public supports are not chosen randomly. First of all, they must apply for research subsidies (or tax credit programmes) and, hence, a self-selection process may take place. Then, beneficiaries of R&D subsidies are selected by a public agency among several applicants. Furthermore, there is no guarantee that supported companies will perform additional research activities as these firms may opportunistically substitute public grants for their own funds (crowding-out hypothesis).

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. A parametric method providing estimates consistent with the Matching procedure is OLS regression, in which firm R&D expenditure (or intensity) is related to some variables indicating whether the company has been publicly supported in research, as well as to other observable covariates influencing both the R&D behaviour of the company and the decisional process of the agency awarding R&D grants. However, in the presence of unobservable characteristics affecting the likelihood of receiving a public support, these two methods yield biased estimates. Parametric approaches circumventing the 'selection on unobservables' problem, which makes public supports potentially endogenous to firm R&D efforts, are the Selection model, the Instrumental-Variables (IV) and the Difference-in-differences (DID) regressions[3]. The potential advantage of these methods is offset by their requirement of additional distributional assumptions

[3] For a review of the different micro-econometric methods for estimating the effect of public supports on business R&D see Cerulli (2010).

(the Selection model), the availability of exogenous instruments or identification variables (IV regression) or of longitudinal data (DID method).

The literature on the effectiveness of R&D subsidies is very extensive and has been surveyed by several papers. 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; in other words, subsidized firms have increased their R&D expenditures more than the amount of public subsidy they received. About one fourth of the firm-level analyses have detected the presence of crowding-out effects while, in the remaining 25%, public subsidies are not found to generate additional privately-funded R&D expenses but the hypothesis of full crowding-out is rejected.

[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 crowding-out. The latter hypothesis is rejected by most studies whereas, in four cases out of twelve, R&D subsidies have increased privately-funded R&D effort. Conversely, there is no evidence in favour of the crowding-out hypothesis. In summary, these studies indicate that public subsidies have positively affected business R&D, although only in a minority of cases private research efforts grew more than the amount of R&D grants received by the companies.

Whilst R&D subsidies are targeted to raise the private marginal return of R&D, in order to fill the gap with the social returns of such activities, tax incentives reduce the cost of doing research (David et al. 2000). The main advantage of R&D tax credits is of not altering the firm choice about the R&D projects to develop, and of avoiding the bias associated with the selection of R&D projects to be funded by the public agency. Hall and Van Reenen (2000) discuss characteristics and problems associated with R&D tax credit. A more recent overview of this line of studies can be found in Becker (2014) and Castellacci and Mee Lie (2015). From this literature it emerges that, on average, a one-percent increase in R&D tax credit raises R&D expenses by around 0.20-0.30% in the short run, and between 1 and 2% in the long run (CPB et al. 2014, p. 20).

3. Data base and variables' description

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 and Spain, and the UK; together, according to Eurostat data, they accounted for 73% of business R&D expenses of the EU in the period under exam.

3.1 Extent of publicly supported firms and types of R&D supports

Table 2 illustrates the number of firms sampled in the EU countries considered and of those reporting a positive share of R&D expenditures on total sales[5]. Excluding Spain, in all countries more than half of the firms are active in R&D.

[Table 2 about here]

In the analysis, we first use a policy (or "treatment") variable defined as a dummy identifying those firms that received public supports to R&D between 2007 and 2009, either in the form of direct subsidies or R&D tax credits, irrespective of the nature of the agency or institution awarding these incentives (regional, national, etc.)[6]. Then, our attention will be paid to the role of R&D subsidies as the available data allow us to precisely identify the group of firms that has benefited from this type of public supports to R&D. Hence, in the second part of the work, we will be able to assess the crowding-in (additionality) hypothesis, i.e. R&D policy did raise net research intensity.

On aggregate, 31% of R&D performing firms received some public supports for their research activities. This confirms that public measures to sustain business R&D have been extensively adopted across European countries (CBP et al. 2014; OECD 2011a and 2011b).

There are remarkable differences among countries in terms of percentage of supported firms: this share is particularly high in Spain, followed by France and Italy, while it is lower in the UK and Germany. These discrepancies are mainly due to the different policy measures pursued by the EU member states. Germany is the only country not offering R&D tax incentives, and this is the main reason why its share of publicly supported firms is the lower than elsewhere. In Germany, R&D

[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; 50-250; more than 250 employees). The survey was conducted in 2010.

[5] We excluded a few companies that reported anomalous or unreliable R&D intensity ratios exceeding 50% of total sales.

[6] The specific query of the questionnaire was "Did the firm benefit from tax allowances and financial incentives for these R&D activities?".

incentives are mostly in the form of non-repayable cash grants which are allocated by numerous programmes. Direct funding is provided by the federal government and the regional states (*Länder*), whose schemes are generally targeted to SMEs. R&D loans or guarantees are alternative to subsidies and are offered by both federal and German states' development banks[7].

In the UK, direct subsidies are by far less diffused than fiscal incentives; the latter represent the largest instrument for supporting business R&D, accounting for 75% of the government budget allocated to innovation support schemes. Fiscal policies are implemented through a deduction from corporation tax liability for R&D expenditures. In 2008-2009 the scheme allowed SMEs to deduct up to 150% of their qualifying expenditures on R&D, while the maximum deduction for larger companies was set to 130%. The number of firms claiming the R&D tax relief was 7,580 in the financial year 2007-2008, and increased to 9,180 in 2009-2010 (HM Revenue & Customs, 2014).

In Italy, direct subsidies to business R&D are provided by the central government through the Ministry of Research's funding scheme (FAR) and by regional governments (especially for co-financing the European Regional Development Fund). In addition to R&D subsidies, a tax credit proportional to the volume of business R&D expenditures was introduced in 2007 (Cantabene and Nascia, 2014). The tax credit amounts to 10% for investments in own research projects, and to 40% for projects in collaboration with universities and public R&D labs. In 2007, 12,446 Italian firms exploited the fiscal incentive. Then, to avoid the overshooting of the planned budget, the Italian government introduced a selection procedure based upon a "first to apply" rule and, as a consequence, the number of firms obtaining the tax deduction declined to 10,069 in 2008 and 5,193 in 2009.

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 increased dramatically. In 2008, direct subsidies and fiscal incentives accounted for 12% and 18% of total private R&D, respectively. Foregone tax liabilities increased from €1.8bn in 2007 to €4.7bn in 2009. Since 2008 a new, more generous regime of tax credit has been introduced, which is based on the volume of R&D expenditures and establishes a 30% rate of tax reduction (up to a threshold of €100m). French companies benefiting from the tax credit increased to 9,760 units in 2008 and to 11,625 in 2009[8].

Finally, 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., 2012). The tax credit is a combination of incremental and volume based systems, by allowing deductions from corporate taxable income (100% of current R&D expenditures) and deductions from the firm's tax liability. Direct subsidies from central government

[7] See www.gtai.de. GTAI (*Germany Trade & Invest*) is the economic development agency of the Federal Republic of Germany.
[8] See Ministère de l'Éducation nationale, de l'Enseignement supérieur et de la Recherche (2011).

are mostly channeled through a public agency providing grants and loans. Firms benefiting from these incentives are less numerous than those exploiting tax credits. Further schemes of direct R&D funding are provided by regional governments.

3.2 Characteristics of R&D performing firms

In the analysis, we account for a large set of firm characteristics to predict either the propensity to obtain R&D support or the intensity of R&D engagement. A detailed definition of the explanatory variables is reported in Table 3.

We control for whether the attitude to engage in R&D, or to apply for R&D public support, changes with the company age (Czarnitzki and Lopes Bento, 2013). Specifically, we include a dummy variable for companies with 20 and more years from establishment, that we label as old aged firms[9].

Firm size is accounted for by a categorical variable taking values from 1 to 3, in relation to whether the company has less than 50, between 50 and 249, and 250 and more employees.

Group affiliation is differentiated according to the nationality of the headquarters (domestic or foreign). This condition should determine the amount of resources available to engage in R&D for affiliated firms, as well as it should influence their capacity to route the procedure for obtaining R&D public support (González et al., 2005; Hussinger, 2008).

We also differentiate EU firms on the basis of their status of direct exporter (i.e. whether they sell abroad their products directly from the home country in 2009) and on whether they have been awarded with a certification for the quality of their products or processes. Moreover, we roughly discriminate firms according to the nature of their management, using a dummy variable for those that are run by individual holders. These firms are likely to better evaluate risks and returns of innovation, avoiding the misalignment of incentives between managers and owners (Driver and Guedes, 2012; Honorè et al., 2015).

We explicitly assess the role of the financial conditions of the firm by means of two dummies. First, we control for the financial structure looking at whether the company mainly rests on bank credit as a mean to finance its activities. For most EU firms, bank credit is the main tool for accessing external finance. In addition, we inspect whether the credit crunch transmitted to R&D performance by reducing the supply of bank credit, inducing firms to demand for more public support. To this aim, we construct a binary variable for those companies that applied for extra credit in 2009 but did not obtain it. This variable provides a direct measure of financial constraints and allows us to assess the impact of the reduced credit availability on firm performance in the

[9] EFIGE classifies firm age into three classes: 0-6 years, 7-19 years, 20 and more years.

aftermath of the crisis. Mancusi and Vezzulli (2014) show that credit constraints mainly affect the firm's decision to undertake R&D projects, but they have a much lower impact on the intensity of R&D efforts. However, to exclude that these two financial variables reflect the general worsening in the business cycle, due to a deterioration in the firm's expectations on future sales (which reduces the rewards to innovation), we use a variable indicating whether the company experienced a turnover reduction between 2008 and 2009.

Another crucial condition that may explain variation across firms in the request for R&D public support is the proportion of R&D performed in-house[10], expressed as the percentage share of total R&D of the company. Firms may indeed use public support as an alternative to R&D outsourcing in order to overcome the financial barriers that typically affect R&D engagement.

[Table 3 about here]

Along with managerial and financial resources, a further key factor influencing R&D engagement and the need to be publicly supported is the firm availability of a highly educated workforce. This is accounted for by the share of graduated employees. Clearly, human capital is very likely to increase the intensity of R&D engagement as it concurs to the creation of new ideas, new products and modes of production (Cantabene and Nascia, 2014). Though, a positive effect for this variable is also expected on the probability to be publicly supported (i.e., treated), for at least a twofold reason. Firstly, companies endowed with a highly educated workforce are better informed about the procedures to follow to participate to public programmes supporting R&D. Secondly, in case of request for direct grants, 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., 2012).

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

Finally, we consider a set of contextual variables capturing whether incentives to undertake R&D, or to request for R&D public support, are shaped by the competitive and technological setting in which the company operates. For this purpose, we consider a dummy variable identifying

[10] In many countries and regions of the EU, R&D support programs may be conditioned on the realization of research in collaboration with other firms and public organizations (Czarnitzki et al., 2007; Busom and Fernandez-Ribas, 2008).

those firms acting as price-taker in the market[11]. We also adopt a proxy for the potential 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)[12]. As the latter variable may reflect only realized productivity improvements, we also include a proxy for the knowledge pool available at the regional level, that we measure by the total share of workers employed in R&D activities (performed by both public and business sectors). However, to discriminate the EU regions on the basis of their economic development and, indirectly, of the different policies that may be pursued to increase regional competitiveness, we include a dummy variable indicating whether the region of the firm is classified as convergence region over the EU program period 2006-2013 (i.e. with less than 75% of the EU GDP per capita). In addition, all specifications include a set of industry dummies, to control for sectoral heterogeneity in R&D behavior[13].

4. Testing the hypothesis of full crowding-out

In this section we evaluate the effectiveness of R&D supports by looking at the total R&D intensity of supported or "treated" firms. These are identified by a dummy variable taking the value of one if they have benefitted from direct subsidies or tax allowances for their R&D activities. At this initial stage, we use the share of total R&D expenses on total sales, i.e. gross of the received public benefit, as outcome variable. Therefore we can only test the hypothesis of full crowding-out, i.e. whether the treated firms reduced their private funds to R&D by an amount equal to (or even greater than) the grant received. This test is performed employing both propensity score matching (PSM) and parametric estimations.

4.1 PSM estimation

We use the procedure of nearest neighbour propensity pcore matching (PSM), which matches each firm that benefitted from public support (R&D subsidies and/or fiscal incentives) with the most similar firm belonging to a control group of non-supported companies. The pairs are selected on the basis of the propensity scores $P(\mathbf{Z}_i)$ yielded by estimating a probit regression for the probability of receiving the treatment ($S_i = 1$):

$$P(\mathbf{Z}_i) = \Pr(S_i = 1 | \mathbf{Z}_i) \tag{1}$$

[11] Price-taking firms are identified as those stating that the price of their products is fixed by the market.
[12] 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).
[13] To preserve confidentiality on firm identity, the EFIGE data base provides industry identifiers in an anonymous form.

where $\mathbf{Z}_i$ is a vector of observable firm characteristics. In our case the PSM compares the difference in the average R&D intensity ($E(\mathrm{RD})$) between the treated firms (identified by the suffix 1) and the non-supported firms (indexed by 0) having a similar $P(\mathbf{Z}_i)$: such a difference represents the Average Treatment Effect on the Treated (ATET). Formally:

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

The PSM procedure avoids a "curse of dimensionality" because all the observable characteristics $\mathbf{Z}_i$ (i.e. the explanatory variables of the probit regression) are summarized by the propensity score which is used as the single matching argument. Such a procedure relies on the conditional independence assumption (CIA) that, in our case, means that the receipt of an R&D support has to be independent of the outcome indicator (R&D intensity), conditional on the set of observable characteristics. As widely known, a formal test for the CIA does not exist but the employment of a wide set of control variables, such as that taken from the EFIGE data base, is a crucial condition for making this assumption to hold.

The left section of Tables A.1-A.5 in the Appendix compares, for each country, the mean values of the control variables between non-supported and supported firms. With a few exceptions, the P-value of the *t*-tests for the mean differences indicates that there are systematic differences between the two groups of firms. Looking at the outcome variable (i.e., the average R&D intensity at firm level) we do not find significant differences between treated and un-treated firms only for Spain.

Table 4 reports the results of the probit regression, showing large disparities across countries[14]. Only three explanatory variables, i.e., the dummy for price-taking firms, that for firms with credit constraints and the regional R&D intensity, do never reach a level of significance of at least 10%. On the other hand, for the majority of countries, there are four factors that are significantly and positively correlated with the probability of getting R&D supports: the size of the firm; the dummy for firms relying almost exclusively on bank credit as a mean of financing; the percentage of R&D carried out in-house; and, to a lesser extent, the dummy for the firm exporting from the home country (see also Carboni, 2011; Czarnitzki and Lopes Bento, 2012 and 2013; Hud and Hussinger, 2014).

The positive impact exerted by the intensity of in-house R&D indicates that firms taking on their shoulders the technological risk of R&D projects, rather than relying on external R&D,

[14] Only for France and Germany we employ the binary variable for credit constraints because, in all the other countries, less than 2% of firms declared that they were unable to get more credit. The dummy identifying the location in a convergence region was dropped for France because in this country there are no regions of this kind. Finally, to improve the matching quality, we employ for Spain the interaction between the percentage of investments on total sales and the size of firms.

demand more (and obtain) R&D supports[15]. Similarly, companies having an almost exclusive reliance on bank loans suffered more the credit crunch at the outset of the financial crisis, demanding relatively more for R&D public support (see Carboni, 2011). These firms have also a low capability of getting more credit to carry out additional R&D projects because, contrarily to investment in physical capital, R&D outlays cannot be used as collaterals in credit negotiations. In other words, bank credit-dependent firms are more prone to apply for public supports. Notice that this condition does not hold in general for all financially constrained firms, i.e., those that unsuccessfully demanded for more credit in the period under exam.

The effect of firm size varies remarkably across countries. In Spain, France, and to a lower extent Italy, the percentage of supported firms is remarkably higher among large firms (i.e. with 250 and more employees) than among medium- and small-sized companies: this is probably due to the presence of tax incentives that do not discriminate between firms on the basis of their size. In fact, in Germany, where R&D tax incentives are not provided, the size class with the highest percentage of subsidized firms is the intermediate one. Similarly, in the UK, tax provisions for large firms are less generous than for SMEs (see Section 3.1).

The percentage of graduated employees is significantly and positively related to the probability of receiving a public support for R&D for French and British firms (see Cerulli and Potì, 2012b). The location of a company in a "convergence region" is positively associated with this probability only in Germany, confirming the findings of earlier studies that firms located in the Eastern regions of this country are more likely to be subsidized (see Hussinger, 2008; Czarnitzki and Lopes Bento, 2012; Hud and Hussinger, 2014). Conversely, in Spain, the location of companies in a relatively developed region reduces the probability of being publicly supported in R&D.

[Table 4 about here]

The next step consists in applying a nearest neighbour (NN) propensity score matching (PSM) to relate each supported (treated) firm with a single non-supported unit (NN=1) with a similar propensity score. The matching procedure is implemented with replacement so that a control unit can be matched with different treated units. To satisfy the requirement of common support, we excluded treated firms with a propensity score lower than the minimum and higher than the maximum achieved by control firms. Moreover, to improve the quality of matching, we also impose

[15] Hussinger (2008) and Czarnitzki and Lopes Bento (2012) employ a similar variable to capture in-house expertise in R&D activities.

a threshold (a "caliper") to the maximum distance between treated firms and control units. If the distance is greater than such a threshold the treated unit is excluded[16].

The number of matched firms after the imposition of both a common support and a 0.005 caliper are reported in the right sections of Tables A.1-A.5 in the Appendix. These tables also show the mean value of the observable characteristics and the outcome variable for supported and control firms. As a confirmation of the validity of our matching procedure, no significant differences arise between these two groups of firms after the matching for the overwhelming majority of observable characteristics. Conversely, significant differences remain in the mean values of the outcome variable which can be imputed to the effect of public support to business R&D.

These differences are illustrated in Table 5 which shows that the estimated ATET are positive and statistically significant for all countries. In Italy, Spain and the UK, the results do not change when a 0.005 caliper is applied; conversely, the effect of public support slightly decreases in France and Germany, although remaining statistically significant (at a 5% level for Germany).

Summing up, on the basis of the PSM estimates developed in this section, we can reject the full crowding-out hypothesis for the major countries of the EU.

[Table 5 about here]

4.2 Parametric estimations

We now present the parametric estimates for the impact of public supports on total R&D intensity, based on a R&D outcome equation describing the relationship between R&D intensity and the treatment indicator S_i and a set of control variables $\mathbf{X}_i$:

$$\mathrm{RD}_i = \mathbf{X}_i'\boldsymbol{\beta} + S_i\gamma + \epsilon_i \qquad (3)$$

The effect of policy support is measured by the parameter γ and can be consistently estimated by OLS, under the assumption of exogeneity of the treatment variable (i.e., unobservable confounders are not at work). In case of failure of this assumption, reverse causality or simultaneity feedbacks lead to biased and inconsistent estimates of the effect of the treatment variable[17]. To overcome this issue, we consider a recursive mixed-process system composed by a linear R&D intensity equation

[16] Adopting a common support leads to drop one observation for Italy, Spain and the UK and six observations for France. By imposing a maximum distance of 0.005, the number of excluded observations is much higher: 12 for Germany and the UK, 19 for Italy, 41 in the case of France and 44 for Spain; notice that this threshold is very restrictive if one considers that the average propensity score for the cross-country sample is 0.315.

[17] 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 one-step Heckman 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.

and an additional probit equation for R&D support (i.e. the potentially endogenous variable), allowing for simultaneity between these two processes[18]. Formally:

$$\begin{aligned} \mathrm{RD}_i &= \mathbf{X}_i'\boldsymbol{\beta} + S_i\gamma + \epsilon_{ii} \\ S_i &= \mathbf{1}(\mathbf{Z}_i'\boldsymbol{\alpha} + u_i > 0) \end{aligned} \tag{4}$$

where the error terms ϵ_i and u_i are jointly normally distributed with zero means and correlation ρ. Simultaneity 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. This recursive system of equations corresponds to the dummy endogenous regressor model proposed by Heckman (1978) and allows accounting for potential endogeneity caused either by observable or unobservable factors. Consistent parameter estimates can be obtained by means of a two-step procedure, as in Hussinger (2008); here, we use instead an efficient full information maximum likelihood approach[19].

Despite the parameters of model (4) are theoretically identified even when the same regressors are included in $\mathbf{X}_i$ and $\mathbf{Z}_i$, to enhance identification it is 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).

For the aim of our analysis, we opt to use variables reflecting differences in some institutional and structural characteristics of the administrative areas in which the firms are located. The set of identification variables (see Table 6 for details) includes: a dummy variable indicating whether the firm is active in an area classified as convergence region (cf. Section 3.2); an index reflecting the institutional quality of the region; the net migration rate; the aging index; the degree of accessibility; the number of municipality twins and the number of interregional (cross-border) collaborations, both expressed as ratios over regional population. In addition, below we use the percentage of firms having Internet access in the assessment of the additionality of R&D subsidies.

[Table 6 about here]

[18] Differently from the probit regressions performed for the PSM, we admit the presence of non-linearities in estimating the two-equation system, by including the square of investment share in the R&D intensity equation and the square of the share of in-house R&D in the equation for R&D support. Non-linear terms increase the predictive capacity of the probit model, facilitating the detection of the simultaneity between the firm's decision to invest in R&D and that to participate in R&D support programmes.

[19] Estimation of the recursive mixed-process model has been carried out using the Conditional Mixed Process (cmp) Stata module by Roodman (2011). Empirical results do not significantly change if we use a two-step estimation procedure.

The rationale behind the use of such variables is that the more dynamic and attractive the region (i.e. with a positive net immigration rate, a low aging rate and good physical and digital infrastructures), and the higher the governance quality (in terms of managed funds, ability to establish partnerships, etc.), the higher is the probability for a firm to receive some public support to R&D. The spirit of this identification strategy follows Einiö (2014) who predicts the probability to participate to R&D support programmes for a sample of Finnish firms by exploiting variation in regional characteristics. In our case, this is justified by the fact that, in all the examined countries, a part of public supports to business R&D is managed by regional governments (especially for co-financing the European Regional Development Fund; see Section 3.1).

[Table 7 about here]

The validity of the exclusion restrictions that we use is confirmed by the value of the Wald test checking the joint significance of the additional identification variables in the probit regression, reported at the bottom of Table 7. The rejection of the null hypothesis of this test indicates that regional variables are good predictors of the probability to be publicly supported,[20] ensuring the consistency of the Wald test assessing the simultaneity of the errors between equations (Roodman, 2011). The latter test assumes the null hypothesis of equation independence (i.e. no endogeneity of the treatment variable) and, hence, in case of rejection system estimates have to be preferred. The uncorrelation between error terms of the two equations indicates that selection on unobservables is not relevant, supporting the validity of the results obtained with PSM and OLS (see Cerulli and Potì 2012b). This hypothesis is rejected only for Spain. The bottom rows of the last column in Table 7 show that, for this country, the impact estimated for the pair of regional variables is in line with our expectations. On the one side, firms located in convergence regions have a lower probability to receive public support to R&D (-0.258); on the other, companies active in regions standing out for a high quality of governance are more likely to participate R&D public programmes and to receive this type of support (0.262).

Table 7 shows that R&D public supports have always a positive and significant effect on the intensity of gross R&D expenditure on turnover. The parameter of R&D supports can be regarded as ATET (see Cerulli and Potì, 2012b) and hence is comparable with PSM estimates. The magnitude of the treatment effect is quite consistent between these two procedures, albeit OLS regression yields slightly smaller coefficients for Italy, the UK and Spain. However, for the latter

[20] A further condition to be satisfied is that the excluded identification variables used in the probit model have to be uncorrelated with R&D intensity. This condition is evaluated by including such variables in both system equations. We find that R&D intensity always remains unaffected by these additional regional indicators (results available upon request).

country, when we account for endogeneity between treatment and outcome variables, the R&D policy variable turns out to be insignificant and the hypothesis of full crowding-out cannot be excluded.

Looking at the other determinants of R&D performance, there is widespread evidence that smaller firms are more intensively engaged in formal research than larger firms, once they overcome the standard barriers to R&D. In France and Germany, this effect adds to a higher R&D effort of young and medium-aged firms. Another firm characteristic that appears to diffusely raise research engagement is the intensity of investment in machinery and equipment and the share of graduate workers. The latter variable turns out to be insignificant only in Italy, whereas it has a relatively strong effect in Germany. The impact of the other explanatory factors is in accordance with our expectations, e.g. direct exporters, firms with a greater share of in-house R&D, or those located in a research-intensive region exhibit a higher share of R&D expenses on total sales, even though these effects are not always significant.

5. Testing the additionality of public subsidies

The analysis performed in the previous section was confined to test whether there were no significant differences between the R&D intensity of the firms that benefitted from public supports (either direct subsidies or fiscal incentives) and that of non-supported firms. However, a crucial insight in policy evaluation is of understanding whether the receipt of public subsidies *increases* the amount of "privately-funded" R&D expenditures. To test the additionality (or crowding-in) hypothesis we assume that the amount of public funds to R&D reported by the firms correspond to direct subsidies. By subtracting this value from the total expenditures in R&D, we compute the intensity of "privately-funded" R&D on total sales. Then, we compare the private R&D intensity of subsidized firms with that of firms not receiving any kind of public supports[21].

Table 8 shows the number of firms reporting public subsidies for R&D and the percentage of these firms on those benefiting from public supports (either subsidies or fiscal incentives). The highest percentage of subsidized firms is recorded in Germany, followed by Spain and France. The large differences across countries are not surprising if one considers that fiscal incentives to R&D are not provided in Germany, while they are extensively used in France and Spain. Surprisingly, only a minority of the supported firms reports the amount of public subsidies received in Italy and the UK (15 and 12%, respectively), suggesting that sampled firms widely under-reported R&D subsidies in these two countries.

[21] Firms that benefited from R&D supports but did not report public funds are excluded from the analysis. In fact they cannot belong to the treated group but, at the same time, should not be included among the control group (also because some of them, although having received R&D subsidies, might not have reported their amounts).

[Table 8 about here]

To compare the effect of public subsidies on both total and privately-funded R&D we first perform a PSM analysis. We predict the probability of receiving R&D public subsidies with a probit regression as in Section 3.2[22]. Due to the low number of firms reporting the amount of R&D subsidies, the matching procedure is performed by imposing only a common support (i.e. we do not apply any caliper).

For the treated and matched units, Table 9 reports the mean share of total and privately-funded R&D expenditures, as well as the mean differences (namely the ATETs). The total intensity of R&D expenses of subsidized firms is always significantly (and remarkably) higher than for non-supported firms. On the other hand, when private R&D intensity is considered, the mean differences are never statistically significant. These findings confirm the absence of crowding-out (either full or partial), but also indicate that public subsidies did not stimulate the recipient firms to spend additional (own) resources on R&D.

[Table 9 about here]

Consistent results arise from parametric estimations, reported in Table 10. By using the mixed model system, endogeneity of the policy variable emerges only for Italy when considering gross R&D intensity as outcome variable (see Section C of Table 3). Therefore, we can safely rely upon OLS estimates to make inference on the impact of R&D subsidies[23]. These estimates indicate that direct granting raised the overall effort of the firms in research activities, as the treatment variable is positively and significantly related to the gross measure of R&D intensity. The estimated ATET for France is around 4, which is moderately higher than the value obtained with the PSM (3.3). By contrast, for all the other countries, OLS estimates yield a value for the ATET below those obtained with the matching procedure. Notice that, irrespectively of the estimation technique adopted and the country under assessment, the ATET on gross R&D intensity is remarkably larger than the one estimated in the previous section (see Tables 5 and 7). It suggests that direct subsidies were particularly effective in enhancing total R&D effort, more than other forms of public support.

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[22] The results of such probit regressions, as well as the mean differences of the explanatory variables before and after the matching, are not reported for the sake of brevity but are available upon request.

[23] For France, we were not able to find out powerful variables able to predict the impact of the potentially endogenous variable and make the Wald test of equations' independence affordable. As a result, for this country, we consider OLS estimates as our preferred results.

[Table 10 about here]

However, R&D subsidies are not significantly associated with the intensity of private R&D expenditures. Accordingly, OLS estimates confirm the rejection of the additionality hypothesis. For Italy, we even find a negative impact of subsidies on private R&D, pointing to a partial crowding-in of R&D subsidies, albeit this effect is significant at a 10% only. This evidence is corroborated by system estimates for gross R&D intensity which reveal that direct funding is unrelated to the measure of total research effort of Italian firms, once accounting for endogeneity of the policy variable[24].

As surveyed 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 over a period between 1990 and 1999. On the contrary, Duguet (2004) and Carboni (2011) provide evidence supporting the additionality hypothesis, respectively for a sample of French and Italian firms. Similarly, Hussinger (2008) estimates that, in Germany, €1 of R&D public funding led to €1 additional private R&D spending between 1990 and 2000. Evidence in favour of the additionality of R&D subsidies for SMEs in Germany is provided by Hud and Hussinger (2014) for the period 2006-2010. However, these authors show that the effect of this policy instrument in 2009, albeit positive, is significantly smaller than in previous years, probably as the financial crisis discouraged subsidized firms to increase their own private funds to R&D. These arguments might explain why, for the period under assessment in the present paper (2007-2009), we do not find evidence for the additionality of R&D subsidies on private R&D intensity.

6. Summary and concluding remarks

In this paper, we have exploited data from a survey conducted on comparable samples of manufacturing firms from the largest EU countries (France, Germany, Italy, Spain and the UK) to perform a micro-econometric evaluation of the effectiveness of R&D public policies. The analysis has been carried separately for each country, so to account for (and identify) the wide differences existing in the public provisions for R&D and in the quality of bodies administering R&D support programs.

The analysis has been developed in two steps and has used different procedures to account for the most relevant econometric issues involved in policy evaluation (selectivity, simultaneity, etc.). First, we have considered the total sample of firms that declare to benefit from public support to R&D, i.e. R&D subsidies and R&D tax incentives taken together (treatment variable). Then, we have refined the analysis focusing on the firms that received direct funding to R&D. By considering

[24] In the system, the probit equation for the R&D public support reveals that Italian firms localised in laggard regions, characterized by a negative rate of migration and a low institutional quality, are less likely to be subsidized for their R&D activities.

two measures of outcome, namely gross and net R&D expenditure on sales, we have been able to test the hypothesis of full crowding-out and that of crowding-in/additionality.

In the first step of the analysis, we have found strong evidence against the hypothesis of full crowding-out for all countries except Spain, for which simultaneity is detected between treatment and outcome variable. As a second step, we have shown that public subsidies are positively correlated with gross R&D intensity, but they have not induced firms to spend additional (own) resources on R&D. Therefore, the hypothesis of additionality of R&D subsidies has to be rejected. This is at odds with the results of some previous studies, but could be due to the fact that the firms' R&D performance, being an average of the values for the years between 2007 and 2009, reflects the effects of the financial crisis and the subsequent downturn. Probably, in response to the crisis, subsidized firms cut or postponed their investment plans so that, contrary to what occurred in previous years, these companies did not undertake additional R&D expenditures.

All in all, our analysis has shown that, albeit ineffective to raise private funds for research, public supports to R&D were not used opportunistically by EU firms to reduce their own efforts. Therefore, we contend that R&D subsidies were effective to avoid the strong drop in business R&D that the financial turmoil would have provoked.

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Tables

Table 1: Firm-level studies on the impact of R&D subsidies in some European countries

	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
Hussinger (2008)	Germany	Private	Selection model	Additionality
Hud and Hussinger (2014)	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: Firms performing R&D and benefiting from R&D supports by country

	France	Germany	Italy	Spain	UK	Total
Number of firms	2961	2924	3007	2765	1989	13646
Firms doing R&D	1488	1539	1644	1195	1040	6906
Percentage of firms doing R&D	*50.25*	*52.63*	*54.67*	*43.22*	*52.29*	*50.61*
Firms with R&D supports	550	268	568	495	292	2173
Percentage of firms with R&D supports (on R&D active firms)	*36.96*	*17.41*	*34.55*	*41.42*	*28.08*	*31.47*

Source: own computation from the EFIGE data base

Table 3: Observable characteristics of R&D performing firms*

Label	Type	Description
Old age	dummy	Equal to 1 for firms with 20 or more years from establishment; 0 otherwise
Size class	categorical	Employment class: “Small” (less than 50 employees); “Medium” (between 20 and 249 employees); “Large” (more than 249 employees)
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
Credit constraint	dummy	Equal to 1 for firms having applied for more credit and being denied; 0 otherwise
Bank credit	dummy	Equal to 1 if the firm relies on bank loans to finance their activity; 0 otherwise
In-house R&D	percentage	Percentage of R&D made in-house
Price taker	dummy	Equal to 1 if firm’s prices that are fixed by the market; 0 otherwise
Sales’ reduction	dummy	Equal to 1 if the firm has experienced sales' reduction during 2009 in comparison with 2008; 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 if the firm 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 4: Results of the probit regression for the receipt of public R&D supports°

	France	Germany	Italy	Spain	UK
Old age	-0.085	-0.264***	-0.020	0.064	0.097
	(0.078)	(0.092)	(0.072)	(0.081)	(0.093)
Size class (cat.)	0.388***	0.124**	0.362***	0.390***	0.039
	(0.063)	(0.062)	(0.064)	(0.095)	(0.080)
Individual holder	-0.388***	0.007	0.06	-0.083	0.059
	(0.084)	(0.116)	(0.098)	(0.094)	(0.127)
Quality certification	0.139*	0.113	0.092	0.328***	0.015
	(0.079)	(0.101)	(0.074)	(0.092)	(0.103)
Foreign group	-0.216*	-0.244	-0.300	0.011	-0.116
	(0.124)	(0.175)	(0.185)	(0.182)	(0.144)
National group	-0.168*	-0.077	0.027	0.211*	0.241*
	(0.098)	(0.143)	(0.106)	(0.123)	(0.132)
Investment/Sales (%)	-0.002	0.005	-0.004	-0.012*	-0.002
	(0.003)	(0.003)	(0.003)	(0.007)	(0.004)
(Inv/Sales)*(Size class)				0.008	
				(0.005)	
Exporter	0.464***	0.181	0.150	0.273***	0.473***
	(0.096)	(0.114)	(0.097)	(0.103)	(0.129)
Graduated employees (%)	0.020***	0.001	0.007	0.004	0.011***
	(0.004)	(0.003)	(0.005)	(0.04)	(0.003)
Credit constraint	0.354	0.046			
	(0.248)	(0.271)			
Bank credit	0.260***	0.097	0.330***	0.293***	0.237**
	(0.076)	(0.096)	(0.070)	(0.087)	(0.093)
In-house R&D (%)	0.001	0.007***	0.006***	0.007***	0.004***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Price taker	0.03	-0.075	0.100	0.081	0.141
	(0.073)	(0.083)	(0.069)	(0.091)	(0.093)
Sales' reduction	-0.136*	-0.014	-0.018	-0.040	0.004
	(0.080)	(0.089)	(0.079)	(0.100)	(0.092)
Regional R&D intensity (%)	0.063	-0.047	0.030	0.027	0.102
	(0.066)	(0.087)	(0.216)	(0.141)	(0.178)
Regional TFP	-0.127	-1.737***	0.111	-0.023	0.074
	(0.297)	(0.445)	(0.307)	(0.283)	(0.403)
Convergence region		0.358***	-0.113	-0.257**	0.025
		(0.139)	(0.146)	(0.115)	(0.213)
Constant	-1.054***	-0.854***	-1.271***	-1.334***	-1.347***
	(0.236)	(0.274)	(0.312)	(0.287)	(0.341)
Lratio	271.96	158.79	137.89	197.39	107.36
Log-likelihood	-844.25	-632.22	-990.80	-711.94	-563.75
Pseudo R^2	0.139	0.111	0.065	0.122	0.087
Observations	1,488	1,539	1,644	1,195	1,040

Industry fixed effects are not reported for the sake of brevity. Standard errors in brackets.
*** p<0.01, ** p<0.05, * p<0.1.

Table 5: Share of R&D expenditures on total sales: mean differences after the matching

	Supported firms	Unsupported firms	ATET
France			
CS	6.873	4.897	1.976***
CS + caliper (0.005)	6.695	4.901	1.796***
Germany			
CS	9.381	7.545	1.836***
CS + caliper (0.005)	9.184	7.574	1.609**
Italy			
CS	7.780	5.681	2.099***
CS + caliper (0.005)	7.885	5.770	2.115***
Spain			
CS	7.229	5.360	1.869***
CS + caliper (0.005)	7.430	5.539	1.891***
UK			
CS	7.340	5.230	2.110***
CS + caliper (0.005)	7.254	5.196	2.058***

CS = Common support. *** p<0.01, ** p<0.05

Table 6: 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)
Convergence region	Dummy	GDP p.c. less than 75% of the EU average in 2004	European Commission
Interregional cooperations	Continuous	Number of project partners participating in Interreg IIIB and IIIC projects/ population (in logs), 2008	Espon
Twin municipalities	Continuous	Number of twin agreements with foreign municipalities/population (in logs), 2012	Espon
Accessibility	Continuous	Multi-modal potential accessibility, standardized index (EU average= 100), 2006	Espon
Internet access	Continuous	Percentage of firms having internet access	Espon

Table 7: OLS and simultaneous system estimates on R&D intensity

	FRANCE OLS	GERMANY OLS	ITALY OLS	UK OLS	SPAIN OLS	SPAIN System	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	R&D int.	R&D int.	R&D int.	R&D int.	R&D int.	R&D int.	R&D support
R&D policy support (ATET)	2.292***	1.840***	1.891***	1.725***	1.636***	0.126	
	(0.453)	(0.552)	(0.415)	(0.455)	(0.525)	(0.989)	
Old age	-1.917***	-1.085***	-0.536	0.679*	-0.699	-0.669	0.0420
	(0.477)	(0.410)	(0.389)	(0.393)	(0.485)	(0.481)	(0.0870)
Size_class (cat.)	-1.121***	-0.366	-1.708***	-1.431***	-1.641***	-1.401***	0.434***
	(0.283)	(0.263)	(0.360)	(0.335)	(0.377)	(0.409)	(0.084)
Individual holder	0.579	-0.562	0.930*	-0.165	-0.184	-0.204	-0.057
	(0.378)	(0.569)	(0.507)	(0.493)	(0.631)	(0.624)	(0.102)
Quality certification	0.735	-0.184	0.307	-0.0482	-0.707	-0.531	0.339***
	(0.476)	(0.383)	(0.380)	(0.461)	(0.537)	(0.526)	(0.098)
Foreign group	-0.229	-0.927	1.546	-1.011*	-1.488*	-1.444*	0.0974
	(0.529)	(0.716)	(1.156)	(0.599)	(0.892)	(0.877)	(0.197)
National group	-0.632	-0.653	0.376	-1.006*	-1.844***	-1.708***	0.227*
	(0.433)	(0.659)	(0.582)	(0.519)	(0.618)	(0.620)	(0.132)
Investment/Sales (%)	0.165***	0.384***	0.273***	0.256***	0.393***	0.393***	-0.0004
	(0.034)	(0.046)	(0.035)	(0.057)	(0.041)	(0.041)	(0.003)
(Investment/Sales)^2	-0.002***	-0.003***	-0.0027***	-0.0022*	-0.0034***	-0.003***	
	(0.0004)	(0.0001)	(0.0005)	(0.001)	(0.0005)	(0.0005)	
Exporter	0.772*	1.169***	0.787	1.080**	0.188	0.325	0.272**
	(0.401)	(0.415)	(0.490)	(0.462)	(0.591)	(0.589)	(0.109)
Graduated employees	0.062**	0.138***	0.0298	0.0599***	0.068***	0.069***	0.002
	(0.025)	(0.020)	(0.027)	(0.018)	(0.025)	(0.024)	(0.004)
Credit constraint	0.286	1.708	1.425*	7.174*	-0.601	-0.679	-0.121
	(1.468)	(1.486)	(0.801)	(4.304)	(0.642)	(0.639)	(0.160)
Bank credit	0.0583	-0.994**	-0.347	-0.296	-0.470	-0.309	-0.0747
	(0.420)	(0.420)	(0.376)	(0.384)	(0.532)	(0.515)	(0.108)
In-house R&D (%)	0.011**	-0.005	0.013	0.016**	-0.002	0.002	0.087
	(0.005)	(0.007)	(0.008)	(0.006)	(0.008)	(0.008)	(0.097)
In-house R&D^2							-0.0002***
							(0.0001)
Price taker	-0.464	-1.377***	-0.423	0.177	-1.176***	-1.125***	0.007
	(0.344)	(0.341)	(0.366)	(0.389)	(0.429)	(0.428)	(0.153)
Sales' reduction	0.0120	-0.323	0.145	-0.335	-0.222	-0.282	0.0291***
	(0.394)	(0.376)	(0.431)	(0.388)	(0.576)	(0.578)	(0.008)
Regional R&D intensity (%)	1.025**	0.714**	0.498	-0.770	0.281	0.350	-0.089
	(0.419)	(0.344)	(1.044)	(0.685)	(0.677)	(0.674)	(0.299)
Regional TFP	-0.008	4.736***	0.831	2.587	-0.499	-0.522	0.324***
	(1.789)	(1.645)	(1.388)	(1.807)	(1.560)	(1.550)	(0.095)
Constant	2.981***	1.950**	4.961***	5.598***	7.231***	7.161***	-1.405***
	(1.076)	(0.955)	(1.568)	(1.360)	(1.376)	(1.372)	(0.298)
Observations	1,488	1,539	1,644	1,040	1,195	1195	
R-squared	0.165	0.269	0.112	0.189	0.215		
Log-pseudolikelihood							-4503.3

Diagnostics on system estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Joint Wald test of significance of identification variables [P-value]	[0.06]	[0.00]	[0.12]	[0.04]	[0.08]		
Wald Test of equation independence (H0=no simultaneity) [P-value]	[0.13]	[0.80]	[0.84]	[0.50]	[0.01]		
<u>Identification variables</u>							
	Twin municipalities	Interregional cooperations	Aging index	Accessibility	Convergence region		
	Migration rate	Migration rate	Institutional quality	Migration rate	Institutional quality		
<u>Estimated impact of identification variables</u>							
Convergence region							-0.258**
							(0.123)
Institutional quality							0.262**
							(0.127)

Robust standard errors in parentheses. Estimates use sample weights. Cols. (1)-(5) are based on OLS. Cols. (6)-(7) are based on the simultaneous mixed-process system. *** p<0.01, ** p<0.05, * p<0.1 denote significance at 1, 5 and 10 percent levels, respectively.

Table 8: Number and percentage of firms reporting public subsidies

	France	Germany	Italy	Spain	UK	Total
Firms with R&D supports	550	268	568	495	292	2173
Firms reporting R&D subsidies	139	87	89	147	36	498
Percentage of firms with R&D subsidies on supported firms	25.27	32.46	15.67	29.70	12.33	22.92

Table 9: Share of R&D expenditures on total sales: mean differences after the matching

		Firms with R&D subsidy	Firms without R&D supports	ATET
France (n=139)	Total R&D intensity	8.410	5.151	3.259***
	Private R&D intensity	5.444	5.151	0.293
Germany (n=87)	Total R&D intensity	10.230	5.920	4.310***
	Private R&D intensity	6.695	5.920	0.775
Italy (n=88)	Total R&D intensity	8.648	5.739	2.909***
	Private R&D intensity	5.305	5.739	-0.433
Spain (n=147)	Total R&D intensity	8.245	4.497	3.748***
	Private R&D intensity	5.395	4.497	0.899
UK (n=35)	Total R&D intensity	8.343	4.686	3.657***
	Private R&D intensity	5.939	4.686	1.253

*** p<0.01, ** p<0.05

Table 10: OLS and system estimates on total and private R&D intensity of firms with R&D subsidies (continues)

	FRANCE-OLS		GERMANY-OLS		ITALY-OLS		ITALY-System	
	(1)	(2)	(3)	(4)	(5)	(6)	(5 bis)	
	Total R&D int.	Private R&D int.	Total R&D int.	Private R&D int.	Total R&D int.	Private R&D int.	Total R&D int.	R&D support
R&D subsidy (ATET)	4.056***	1.043	3.223***	-0.446	2.245**	-1.280*	0.609	
	(1.046)	(0.899)	(1.004)	(0.667)	(0.909)	(0.712)	(1.311)	
Old age	-1.701***	-1.415***	-0.762*	-0.603	-0.292	-0.351	-0.292	0.0420
	(0.520)	(0.486)	(0.438)	(0.411)	(0.437)	(0.433)	(0.433)	(0.126)
Size (categorical)	-0.724**	-0.450	-0.308	-0.225	-1.144**	-0.931**	-1.070**	0.265**
	(0.313)	(0.289)	(0.278)	(0.270)	(0.463)	(0.448)	(0.452)	(0.109)
Individual holder	0.728*	0.906**	-0.221	-0.0448	1.339**	1.085*	1.312**	-0.0582
	(0.436)	(0.397)	(0.577)	(0.554)	(0.584)	(0.574)	(0.576)	(0.168)
Quality certification	0.884*	0.741	-0.102	-0.0882	0.580	0.485	0.596	0.0190
	(0.517)	(0.481)	(0.401)	(0.370)	(0.425)	(0.418)	(0.420)	(0.137)
Foreign group	0.0491	-0.00461	-1.163	-0.802	2.671*	2.464*	2.582*	-0.465
	(0.629)	(0.580)	(0.725)	(0.695)	(1.393)	(1.396)	(1.384)	(0.328)
National group	-0.453	-0.526	-0.498	-0.131	0.719	0.483	0.697	-0.0902
	(0.488)	(0.449)	(0.698)	(0.690)	(0.680)	(0.667)	(0.672)	(0.189)
Investment/Sales (%)	0.144***	0.132***	0.343***	0.345***	0.223***	0.229***	0.225***	0.004
	(0.0361)	(0.0328)	(0.0477)	(0.0391)	(0.0391)	(0.0384)	(0.039)	(0.005)
(Investment/Sales)^2	-0.001***	-0.001***	-0.0029***	-0.003***	-0.002***	-0.002***	-0.002***	
	(0.0004)	(0.0003)	(0.0008)	(0.000)	(0.0005)	(0.000)	(0.0001)	
Exporter	0.705*	0.707*	0.902**	0.612	0.407	0.296	0.435	0.131
	(0.423)	(0.406)	(0.435)	(0.420)	(0.537)	(0.534)	(0.532)	(0.176)
Graduated employees	0.0410	0.0300	0.139***	0.139***	-0.0242	-0.0248	-0.0228	0.001
	(0.0331)	(0.0293)	(0.0211)	(0.0211)	(0.0276)	(0.0275)	(0.0275)	(0.008)
Credit constraint	-0.693	-0.737	1.847	1.738	1.140	1.247	1.192	0.251
	(1.666)	(1.435)	(1.588)	(1.504)	(0.926)	(0.915)	(0.910)	(0.191)
Bank credit	0.164	0.0946	-0.947**	-0.876**	-0.250	-0.251	-0.180	0.368***
	(0.480)	(0.445)	(0.454)	(0.430)	(0.435)	(0.424)	(0.430)	(0.141)
In-house R&D (%)	0.011*	0.009*	-0.001	0.0004	0.0155	0.0196**	0.018*	0.032***
	(0.006)	(0.005)	(0.008)	(0.007)	(0.010)	(0.010)	(0.010)	(0.010)
(In-house R&D)^2								-0.0003**
								(0.0001)
Price taker	-0.813**	-0.669*	-1.268***	-1.071***	-0.769*	-0.633	-0.737*	0.138
	(0.396)	(0.369)	(0.363)	(0.342)	(0.413)	(0.407)	(0.407)	(0.125)
Sales reduction	0.280	0.180	-0.386	-0.367	0.276	0.152	0.246	-0.183
	(0.435)	(0.414)	(0.394)	(0.379)	(0.460)	(0.456)	(0.455)	(0.138)
Regional R&D intensity (%)	0.852*	0.768*	0.873**	0.821**	0.436	0.747	0.495	0.307
	(0.451)	(0.409)	(0.359)	(0.331)	(1.177)	(1.159)	(1.166)	(0.336)
Regional TFP	-0.561	-0.139	5.094***	4.712***	0.917	0.658	0.548	-1.043***
	(1.937)	(1.770)	(1.708)	(1.573)	(1.431)	(1.404)	(1.435)	(0.384)
Observations	1,077	1,077	1,358	1,358	1,165	1,165	1,165	
R-squared	0.165	0.101	0.243	0.239	0.090	0.084		
Log-pseudolikelihood							-4068,4	

Diagnostics on system estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(5 bis) Total R&D int.	(5 bis) R&D support
Joint Wald test of significance of identification variables [P-value]	[0.20]	[0.12]	[0.01]	[0.01]	[0.00]	[0.01]		
Wald Test of equation independence (H0=no simultaneity) [P-value]	[0.07]	[0.00]	[0.41]	[0.16]	[0.07]	[0.24]		
<u>Identification variables</u>								
	Twin municipalities		Interregional cooperations		Migration rate			
	Migration rate		Migration rate		Institutional quality			
<u>Estimated impact of identification variables</u>								
Migration rate								-0.913***
								(0.280)
Institutional quality								0.351**
								(0.176)

Table 10: OLS and system estimates on total and private R&D intensity of firms with R&D subsidies (continued)

	UK		SPAIN	
	(7) Total R&D int.	(8) Private R&D int.	(9) Total R&D int.	(10) Private R&D int.
R&D subsidy (ATET)	2.165**	-0.0585	3.039***	-0.162
	(0.996)	(0.909)	(0.919)	(0.786)
Old age	0.932**	0.905**	-0.518	-0.467
	(0.428)	(0.427)	(0.578)	(0.556)
Size (categorical)	-1.141***	-1.068***	-1.378***	-1.028**
	(0.382)	(0.384)	(0.525)	(0.490)
Individual holder	-0.231	-0.212	0.115	-0.125
	(0.592)	(0.583)	(0.759)	(0.748)
Quality certification	0.370	0.421	-0.716	-0.670
	(0.500)	(0.500)	(0.616)	(0.596)
Foreign group	-0.400	-0.421	-0.946	-0.823
	(0.711)	(0.708)	(1.297)	(1.279)
National group	-0.852	-0.811	-2.320***	-1.856***
	(0.640)	(0.637)	(0.735)	(0.668)
Investment/Sales (%)	0.280***	0.268***	0.428***	0.403***
	(0.0404)	(0.0402)	(0.0451)	(0.0443)
(Investment/Sales)^2	-0.003***	-0.003***	-0.003***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
Exporter	0.959**	0.906*	0.269	0.211
	(0.481)	(0.485)	(0.662)	(0.629)
Graduated employees	0.0454**	0.0422**	0.0679**	0.0576*
	(0.0202)	(0.0192)	(0.0324)	(0.0302)
Credit constraint	8.206*	7.366	-0.664	-0.615
	(4.516)	(4.554)	(0.732)	(0.708)
Bank credit	-0.440	-0.449	-0.530	-0.462
	(0.439)	(0.437)	(0.632)	(0.614)
In-house R&D (%)	0.0165**	0.0164**	0.00135	-0.00746
	(0.00713)	(0.00712)	(0.00957)	(0.00887)
Price taker	0.211	0.212	-1.297**	-1.094**
	(0.446)	(0.445)	(0.512)	(0.483)
Sales reduction	-0.401	-0.441	0.0893	0.389
	(0.447)	(0.445)	(0.674)	(0.629)
Regional R&D intensity (%)	-0.977	-0.759	0.495	0.766
	(0.731)	(0.732)	(0.800)	(0.789)
Regional TFP	3.535*	2.776	0.297	-0.228
	(2.098)	(2.096)	(1.758)	(1.719)
Observations	784	784	847	847
R-squared	0.165	0.147	0.246	0.219
Diagnostics on system estimates				
Joint Wald test of significance of identification variables [P-value]	[0.04]	[0.04]	[0.01]	[0.01]
Wald Test of equation independence (H0=no simultaneity) [P-value]	[0.44]	[0.56]	[0.25]	[0.24]
Identification variables				
	Accessibility		Convergence regions	
	Migration rate		Internet access	
Estimated impact of identification variables				
Migration rate				
Institutional quality				

Robust standard errors in parentheses. OLS Estimates based on sample weights. Constant unreported.
*** p<0.01, ** p<0.05, * p<0.1 denote significance at 1, 5 and 10 percent levels, respectively

Appendix

Mean differences in observable characteristics and outcome variable (*R&D intensity*) before and after matching (by imposing common support and a 0.005 caliper)

Table A.1 – France

	Before Matching			After matching		
	Supported (N=550)	Unsupported (N=938)	P-value of T-test	Supported (N=509)	Unsupported (N=509)	P-value of T-test
Old age	0.702	0.686	0.511	0.703	0.684	0.497
Size class (cat.)	1.727	1.356	0.000	1.662	1.656	0.897
Individual holder	0.456	0.662	0.000	0.475	0.460	0.616
Quality certification	0.680	0.537	0.000	0.658	0.654	0.895
Foreign group	0.215	0.126	0.000	0.204	0.193	0.638
National group	0.289	0.237	0.025	0.277	0.324	0.101
Investment/Sales (%)	7.356	8.474	0.099	7.478	9.262	0.045
Exporter	0.891	0.721	0.000	0.882	0.862	0.348
Graduated employees (%)	5.569	1.167	0.000	3.267	2.595	0.289
Credit constraint	0.029	0.016	0.088	0.029	0.033	0.720
Bank credit	0.404	0.337	0.010	0.401	0.411	0.750
In-house R&D (%)	49.533	49.267	0.850	49.334	47.774	0.349
Price taker	0.460	0.417	0.105	0.450	0.493	0.168
Sales’ reduction	0.684	0.720	0.141	0.694	0.705	0.682
Regional R&D intensity (%)	1.416	1.329	0.014	1.389	1.364	0.548
Regional TFP	0.041	0.026	0.069	0.035	0.034	0.962
R&D intensity	*6.887*	*4.744*	*0.000*	*6.695*	*4.901*	*0.000*

Table A.2 – Germany

	Before Matching			After matching		
	Supported (N=268)	Unsupported (N=1271)	P-value of T-test	Supported (N=256)	Unsupported (N=256)	P-value of T-test
Old age	0.470	0.671	0.000	0.488	0.488	1.000
Size class (cat.)	1.687	1.621	0.179	1.684	1.758	0.261
Individual holder	0.765	0.784	0.483	0.762	0.766	0.917
Quality certification	0.799	0.733	0.026	0.797	0.758	0.289
Foreign group	0.067	0.084	0.354	0.070	0.082	0.618
National group	0.116	0.107	0.679	0.117	0.102	0.572
Investment/Sales (%)	13.065	11.169	0.020	12.756	13.385	0.621
Exporter	0.854	0.807	0.070	0.848	0.867	0.528
Graduated employees (%)	8.601	6.783	0.061	8.144	8.934	0.592
Credit constraint	0.029	0.020	0.296	0.031	0.020	0.400
Bank credit	0.284	0.228	0.053	0.277	0.270	0.843
In-house R&D (%)	21.638	10.387	0.000	19.996	21.699	0.581
Price taker	0.384	0.400	0.641	0.398	0.391	0.857
Sales’ reduction	0.675	0.655	0.531	0.680	0.695	0.704
Regional R&D intensity (%)	1.308	1.422	0.001	1.333	1.349	0.724
Regional TFP	0.183	0.252	0.000	0.192	0.206	0.239
Convergence region	0.340	0.117	0.000	0.316	0.277	0.334
R&D intensity	*9.381*	*7.006*	*0.000*	*9.184*	*7.574*	*0.050*

Table A.3 – Italy

	Before Matching			After matching		
	Supported (N=568)	Unsupported (N=1076)	P-value of T-test	Supported (N=549)	Unsupported (N=549)	P-value of T-test
Old age	0.664	0.645	0.448	0.658	0.650	0.800
Size class (cat.)	1.488	1.246	0.000	1.446	1.441	0.892
Individual holder	0.727	0.777	0.025	0.736	0.745	0.731
Quality certification	0.695	0.600	0.000	0.692	0.687	0.845
Foreign group	0.051	0.046	0.679	0.051	0.040	0.386
National group	0.218	0.152	0.001	0.202	0.230	0.272
Investment/Sales (%)	8.843	9.514	0.228	8.952	9.349	0.526
Exporter	0.882	0.823	0.002	0.878	0.869	0.650
Graduated employees (%)	2.396	1.220	0.002	1.955	1.490	0.294
Bank credit	0.708	0.578	0.000	0.699	0.723	0.387
In-house R&D (%)	14.854	7.839	0.000	14.002	12.534	0.378
Price taker	0.377	0.336	0.095	0.375	0.395	0.496
Sales' reduction	0.748	0.746	0.931	0.743	0.721	0.414
Regional R&D intensity (%)	0.993	0.981	0.208	0.992	0.989	0.790
Regional TFP	-0.144	-0.153	0.198	-0.145	-0.145	0.997
Convergence region	0.065	0.084	0.182	0.067	0.071	0.812
R&D intensity	*7.769*	*6.243*	*0.000*	*7.885*	*5.770*	*0.000*

Table A.4 – Spain

	Before Matching			After matching		
	Supported (N=495)	Unsupported (N=708)	P-value of T-test	Supported (N=451)	Unsupported (N=451)	P-value of T-test
Old age	0.612	0.544	0.020	0.599	0.596	0.946
Size class (cat.)	1.578	1.189	0.000	1.477	1.503	0.555
Individual holder	0.596	0.720	0.000	0.630	0.579	0.118
Quality certification	0.810	0.649	0.000	0.794	0.800	0.804
Foreign group	0.103	0.047	0.000	0.095	0.102	0.738
National group	0.208	0.103	0.000	0.188	0.200	0.674
Investment/Sales (%)	13.063	14.819	0.056	13.251	12.754	0.600
Investment/Sales* Size class	19.307	16.699	0.041	18.381	17.525	0.554
Exporter	0.859	0.737	0.000	0.845	0.843	0.927
Graduated employees (%)	5.642	3.021	0.000	4.951	4.357	0.470
Bank credit	0.733	0.651	0.003	0.721	0.681	0.191
In-house R&D (%)	11.657	4.550	0.000	9.186	9.854	0.677
Price taker	0.283	0.233	0.051	0.271	0.239	0.285
Sales' reduction	0.802	0.809	0.788	0.805	0.780	0.367
Regional R&D intensity (%)	1.140	1.080	0.009	1.139	1.061	0.002
Regional TFP	-0.065	-0.091	0.011	-0.067	-0.092	0.032
Convergence region	0.182	0.263	0.001	0.191	0.228	0.165
R&D intensity	*7.222*	*6.809*	*0.348*	*7.430*	*5.539*	*0.000*

Table A.5 – UK

	Before Matching			After matching		
	Supported (N=292)	Unsupported (N=748)	P-value of T-test	Supported (N=280)	Unsupported (N=280)	P-value of T-test
Old age	0.647	0.585	0.068	0.650	0.621	0.483
Size class (cat.)	1.490	1.408	0.052	1.482	1.446	0.482
Individual holder	0.736	0.770	0.252	0.739	0.789	0.164
Quality certification	0.736	0.691	0.152	0.732	0.668	0.097
Foreign group	0.192	0.186	0.825	0.193	0.179	0.664
National group	0.195	0.123	0.003	0.186	0.153	0.312
Investment/Sales (%)	7.733	9.064	0.104	7.971	7.152	0.323
Exporter	0.911	0.773	0.000	0.907	0.914	0.767
Graduated employees (%)	8.771	4.091	0.000	6.825	6.071	0.546
Bank credit	0.384	0.305	0.015	0.369	0.357	0.792
In-house R&D (%)	23.476	16.290	0.002	22.750	21.475	0.669
Price taker	0.366	0.305	0.056	0.368	0.400	0.435
Sales’ reduction	0.596	0.612	0.627	0.596	0.593	0.932
Regional R&D intensity (%)	1.189	1.159	0.139	1.180	1.168	0.639
Regional TFP	-0.042	-0.047	0.569	-0.042	-0.039	0.757
Convergence region	0.045	0.051	0.674	0.043	0.046	0.838
R&D intensity	*7.418*	*5.198*	*0.000*	*7.254*	*5.196*	*0.000*