

Research cooperation within and across regional boundaries.

Does innovation policy add something? *

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Abstract

The paper aims at showing how policy makers can stimulate firms' cooperation with research organizations. We argue that the receipt of a R&D subsidy can be effective in that, but to a greater extent for cooperating within the regional boundaries than across them. Firms' propensity to cooperate with extra-regional, and possibly unique and cutting-edge, research partners is assumed to increase by increasing amount of public support, which has to overcome a minimum threshold for firms to cover the fixed costs of distant interactions. These research hypotheses are tested with respect to a sample of firms located in an Italian region (Emilia-Romagna). Propensity score matching is applied to identify the impact generated by the receipt of the R&D subsidy, while a generalised propensity score technique is employed to investigate the impact of an increasing amount of public support. All of the hypotheses are not rejected. Firms' cooperation with research organizations is policy sensible, but the size of the support is crucial for its effects.

Keywords: Industry-Research Cooperation, Regional Innovation Systems, Behavioural Additionality

JEL Classification: O32; O38; R11; R58

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1 Introduction

Innovation cooperation is a core issue in the research and in the policy agenda. In the last decade, it has been one of the pillars of the system approach to innovation and innovation policy, at both the national and regional level (e.g. [Lundvall, 1992](#); [Cooke et al., 1997](#); [Edquist, 2000](#)). More recently, it has stimulated the debate on the so-called “open innovation” mode (e.g. [Chesbrough et al., 2006](#); [Dahlander and Gann, 2010](#)) and a policy-shift from “knowledge stocks” to “knowledge flows” (e.g. [European-Commission, 2010a,b](#)).

Cooperating with research organisations (ROs) (universities and research institutes) is particularly important for industrial innovation. It enables firms to access newly generated knowledge from the world of science and to share the costs and risks of research ([Mansfield, 1991, 1995](#); [Mansfield and Lee, 1996](#)).¹

The role of firms’ cooperation with ROs has been widely recognised also at the regional level. Within the regional boundaries, it contributes to shaping the ‘knowledge-base’ and the technological profile of the Regional Innovation System (RIS) (e.g. [Cooke et al., 1997](#); [Asheim and Coenen, 2005](#)). Cooperating with RO is also important across the regional boundaries, in order to allow regions to open up, enter into broader (e.g. global) innovation networks, and upgrade their competencies (e.g. [Krätke and Brandt, 2009](#); [Chaminade, 2011](#)).

In spite of its relevance, the results obtained by regional studies on the cooperation between firms and ROs still hesitate to get distilled into science and technology policies to foster it ([Hassink, 2002](#); [Todtling and Trippl, 2005](#)). Different reasons are responsible for that. On the one hand, the analysis of the barriers which hamper this kind of interaction, and which thus require a policy intervention, is quite recent and mainly focused on the national level (e.g. [Mora-Valentin et al., 2004](#); [Bruneel et al., 2010](#)). On the other hand, the policy outcome in addressing these barriers is hard to identify. Industry-research cooperation is not one-shot like, but rather evolves over time and often becomes very unstable ([Lhuillery and Pfister, 2009](#)). Furthermore, what innovation policy actually “adds” to the cooperative behaviours that firms would have however established, searching for a competitive advantage, is hard to disentangle. Non-standard econometric techniques are required, but so far these have been mainly applied to assess the policy impact on firms’ innovation inputs (e.g. R&D expenditure) and outputs (e.g. patents) ([Georghiou, 2004](#)).

In order to fill this gap, we investigate the extent to which networking

¹Cooperation (R&D partnerships, in particular) with other firms also plays important functions ([Kamien et al., 1992](#); [Pisano, 1990](#); [Kesteloot and Veugelers, 1995](#); [Greenlee and Cassiman, 1999](#)) and has been attracting a lot of attention (e.g. [Belderbos et al., 2004](#); [Hagedoorn and Van Kranenburg, 2003](#)).

activities firms undertake as part of a RIS are affected by an innovation supporting regional scheme designed also to foster industry-research interactions: in particular a regional R&D subsidy which includes cooperation with ROs among the activities eligible for public funding.

We put forward a number of research hypotheses and test them in an empirical study of the Emilia-Romagna region of Italy. Cooperation with ROs is dealt with as an element of the “behavioural additionality” of innovation policy (e.g. [Antonioli and Marzucchi, 2012](#)). We investigate it by using an original, firm-level dataset, containing information on policy funding, as well as pre-policy characteristics and post-policy behaviours and performances. A set of propensity score matching techniques is first applied to it. The effect that an increase in the amount of subsidy has on the geographical extent of firms’ cooperation with ROs is then investigated by applying the generalised propensity score technique ([Hirano and Imbens, 2004](#)). This is an important value added with respect to the extant literature.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature and puts forward the hypotheses to be tested. Section 3 presents the empirical application and Section 4 discusses its results. Section 5 concludes.

2 Background literature and hypotheses

The role of the link between science and technology for firms’ innovation has been investigated since long (e.g. [Allen, 1977](#); [Tushman and Katz, 1980](#)). A number of empirical studies have shown that several (and radical) innovations have their roots in such a link between firms and RO (e.g. [Mansfield, 1991, 1995](#); [Mansfield and Lee, 1996](#); [Cockburn and Henderson, 2001](#)). Firstly, RO can provide firms with complementary knowledge and with other intangible assets (e.g. human capital), which are necessary for them to innovate, but not easily contracted and monitored through market-based transactions ([Sinha and Cusumano, 1991](#); [Katsoutacos and Ulph, 1998](#)). Secondly, in partnerships with RO firms can share the risks and costs of R&D and try to benefit from economies of scale ([Hagedoorn, 1993](#); [Tether, 2002](#)) (on the motivations and patterns of innovation cooperation, see [Caloghirou et al. \(2003\)](#)).

Firms’ cooperation with ROs are also important at the regional level. Along with inter-firm networks (e.g. R&D partnerships) and other institutional linkages (e.g. those with local banks), they give rise to location-specific innovation patterns, of which Regional Innovation Systems (RISs) are one of the most celebrated example ([Cooke et al., 1997](#)). In the RIS framework, industry-research interactions represent the “knowledge fabric” of the system, where the scientific core is developed before being accessed and transformed into new products and processes by the technology sub-

system (Fritsch, 2001). In the companion perspectives of learning-regions and learning-in-space (Florida, 1995; Hassink and Klaerding, 2012), these interactions generate the “analytical knowledge base” (i.e. *know-why* kind of knowledge) that activate the Science and Technology Innovation (STI) mode (Asheim, 2012). Firms’ cooperation with ROs thus contributes to define the “knowledge-base”² of the region, making arise a variety of RIS (learning regions), with different innovation potential (Asheim and Coenen, 2005, 2006) and different (possibly smart) specialization patterns (Wintjes and Hollanders, 2011).³

Although beneficial in terms of innovation outcomes, cooperative relationships between firms and ROs are hampered by several barriers, which create the need of a policy support for them (Busom and Fernández-Ribas, 2008), also and above at the regional level (e.g. Hassink, 2002). Irrespectively from the actual location of the RO, regional firms could find costly to establish and manage a relationship with partners which have different incentives and objectives: for example, long-run, exploratory research of basic knowledge vs. short-run, exploitative research of applied knowledge (Carayol, 2003). Their approaches to IPOs are often conflicting, resulting in divergent quality and evaluations of the respective patents (Valentin and Jensen, 2007). Their stocks of knowledge capital can be quite unbalanced, hampering firms’ absorption of ROs’ knowledge (Hall et al., 2003). These implicit costs, which have been detected in general (Bruneel et al., 2010), can be exacerbated in those regional contexts (e.g. “peripheral” and “old industrial regions”) whose industrial structure is dominated by SMEs characterised by a low-tech specialisation pattern (Fritsch and Schwirten, 1999; Mohnen and Hoareau, 2003; Todtling and Trippl, 2005).

Public support to firms’ innovation – such as, for example, an R&D subsidy to firms’ networking – can be used by the recipient firms to restore the incentives to cooperate with RO and to reduce the costs of managing the relative partnerships (Vilasuso and Frascatore, 2000). Hence, the policy can augment the extent and/or the number of these collaborations,⁴ generating what has been called “behavioural-additionality” (e.g. ?). Indeed, not only the policy intervention is expected to increase firms’ innovative investment (“input-additionality”) with respect to similar ‘non-treated’ ones, and innovative outputs (“output-additionality”). It might also lead to a

²In the region, the STI mode combines with the Doing-Using-Interacting (DUI) mode, which generates the “synthetic” (i.e. *know-how*) and the “symbolic” (i.e. *know-who*) knowledge-base of it. The relative weight of the two modes and their link is also part of the knowledge-base specification of the region (Asheim, 2012).

³The cooperation between firms and RO – universities in particular – is also crucial for regions to “generate” new entrepreneurialism and “develop” the regionalisation of production and regulation (Gunasekara, 2006).

⁴Consistently with this expectation, government support appears generally significant among the determinants of science-technology relationships (e.g. Mohnen and Hoareau, 2003; Capron and Cincera, 2003).

“change in a company’s *way of* undertaking R&D” (Buisseret et al., 1995, p.590, additional emphasis). In the case of regional firms, as we said, this behavioural-additionality is particularly important. A R&D subsidy, which includes cooperation with ROs among the activities eligible for public funding, can make the knowledge-base of the RIS “thicker” and increase its innovation potential. The following hypothesis is thus worthwhile testing:

HP1: *The receipt of a R&D subsidy increases firms’ cooperation with ROs.*

Cooperation of regional firms is particularly important when the partner is a RO located across the regional boundaries. This kind of interaction enables regional firms to access an external (possibly international) pool of resources and capabilities, which could complement the local ones (Asheim and Coenen, 2006). It enhances knowledge generation and circulation in the region (Bunnell and Coe, 2001; Bathelt et al., 2004), it increases the diversity of the ideas within the local knowledge base (MacKinnon et al., 2002; Gertler and Levitte, 2005; Boschma and Ter Wal, 2007), and it finally attenuates the risk that the RIS gets locked in its current knowledge-base, making it obsolete for competing in a global scenario (Hassink, 2005; Giuliani, 2005).⁵

However, extra-regional cooperation is also more costly than the regional one, as it is characterised by lower “geographical proximity”: *coeteris paribus* the costs of travelling are higher, the time for making it work is longer, and the communication is harder (Katz, 1994; Fritsch and Schwirten, 1999; Mora-Valentin et al., 2004). This is consistent with the studies which find that geographical proximity facilitates interaction between science and technology (e.g. Landry et al., 1996; Vedovello, 1997; Arundel and Geuna, 2004; Mora-Valentin et al., 2004; Levy et al., 2009). However, this does not entail that geographical proximity is required for successful knowledge exchange, as organizational proximity (Knoben, 2009; Knoben et al., 2008) and/or social proximity (Breschi and Lissoni, 2009) could compensate for its lack. Still, relying on this non-geographical “vicinities” is not for free and could be sometimes difficult to be pursued by regional firms.⁶

This argument has an important implication for the impact that the regional policy can have on innovation cooperation. The extent to which a policy support to R&D can cover the firms’ costs for cooperating is higher for regional than for extra-regional cooperation. Accordingly, and still *coeteris paribus*, the policy will be more likely to enhance regional cooperation than

⁵This issue is currently at the frontier of regional studies. Belussi et al. (2010), for example, refer to an *Open Regional Innovation System* (ORIS) perspective, in which not only do innovation processes overcome the boundaries of the organisation, but also of the region.

⁶Regional firms might have to discount the “liability of foreignness” in cooperating across the national boundaries (Zaheer, 1995), and they might suffer from the socio-cultural and techno-economic gap which often separate partners of different regions, even in the same national environment (e.g. Evangelista et al., 2002; Tallman and Phene, 2007).

the extra-regional one. More precisely, in the behavioural-additionality perspective that we are following, the simple participation in the R&D subsidy scheme (disregarding the amount of support) can be assumed to make the funded firms more prone to interact with regional ROs than with extra-regional ROs, when compared with non-treated firms. In other words, the simple receipt of the subsidy could not be enough to overcome (also) the costs of distant cooperation and make funded firms more cooperative within than across the regional boundaries. We thus put forward the following hypothesis:

HP2: The receipt of a R&D subsidy increases more firms' cooperation with regional than with extra-regional ROs.

It should be noted that HP2 does not amount to stating that regional innovation policy is ineffective in stimulating extra-regional cooperation with RO. This stimulus may require a quite substantial and qualified policy action. Investigating the circumstances under which the policy funding enhances the interactions with extra-regional ROs is particularly important: when firms collaborate with real research excellences located beyond the regional borders, they can renew their knowledge base, and, in turn, that of the region in which they operate.

From a theoretical point of view, the evolutionary-cognitive perspective which underpins the notion of RIS (Uyarra, 2010) would predict that, for this to be the case, regional firms would need to search by 'exploring' new knowledge sources out of their current path, possibly by selecting out those which are already 'exploited' and/or exploitable (March, 1991). In other words, in order to bring new ideas in-house, regional firms should use cooperation to overcome the constraint of local search and creates some "holes" in their existing geographical (and technological) context (Rosenkopf and Almeida, 2003). In management studies, "boundary-spanning exploration" – with respect to both the organizational and technological boundaries of the firm – has been shown to be crucial for obtaining new knowledge with the greatest impact on subsequent technological evolution (Rosenkopf and Nerkar, 2001). Similarly, in regional studies, spanning the geographical boundaries of the region has also appeared important for pursuing innovation and competitiveness (Grotz and Braun, 1997), to a greater extent when it is also a spanning of the national boundaries, across more substantial cultural distances (Tallman and Phene, 2007; Phene et al., 2006). Recent empirical contributions investigating industry-research collaborations develop from a similar theoretical argument: firms looking for cutting-edge and diverse research partners are more likely to establish a collaboration with a RO disregarding the location of this latter (Belussi et al., 2010; D'Este and Iammarino, 2010; Laursen et al., 2011). In synthesis, the real adding-value cooperation that regional firms search across the regional boundaries can be claimed to be that which runs against the losses of geographical proximity

(e.g. personnel interaction, knowledge exchange, face-to-face contacts) – and eventually of cognitive-institutional proximity (Boschma, 2005) – and face the additional costs that distant cooperation entails.⁷ On this basis, the policy role in fostering extra-regional cooperation crucially depends on the extent to which the amount of the public subsidy can cover its costs. Hence, in principle we can expect that the higher the amount of the R&D subsidy is, the higher the degree of coverage, and, in turn, the higher the propensity of cooperating extra-regionally will be.

However, an important specification should be added. Establishing a distant cooperation with (and/or switching from a local to) an extra-regional partner require regional firms to face important, up-front fixed costs. Local firms need to adopt more complex (e.g. multi-language) organizational search routines for identifying more geographically distant partners (Ebers and Grandori, 1997; Knoblen and Oerlemans, 2012). They are asked to manage the eventual manifold ‘institutionalisation’ (e.g. different sources of contractual rules and regulating procedures, in different geographical contexts) of the cooperative relationship (Ranson et al., 1980; Bonaccorsi and Piccaluga, 1994). Last, but not least, they need to build-up a more powerful absorptive capacity (mainly, through R&D and human capital investments) for accessing and assimilating the knowledge of more cognitively distant and/or still unexplored sources (Nooteboom, 2000). This is a crucial aspect as the search for geographically distant RO is also motivated by the firm’s willingness to interact with brand-new and unique knowledge sources (e.g. Belussi et al., 2010; D’Este and Iammarino, 2010; Laursen et al., 2011).

In other words, these are the fixed costs implied by the loss of geographical proximity that firms need to offset for cooperating successfully.⁸

The need to overcome these costs can create indivisibility in the ‘production’ of extra-regional cooperation. Regional firms could thus find this cooperation inconvenient, unless it overcomes a minimum efficient scale in terms of number or/and size of innovative projects. The policy implication of this argument is quite straightforward. Suppose that in order to stimulate regional firms to cooperate more extra-region, policy-makers think to increase the amount of the R&D subsidy. Unless this amount would allow them to

⁷It should be noted that we are not claiming that distant cooperation is better than close one for regional innovativeness, as much as we did not claim the reverse in presenting HP2. We rather claim that the two kinds of cooperation are both useful, but for different purposes and with respect to different partners (Broström, 2010; Ponds et al., 2007). In this last respect, the hypothesis that a geographical variety of knowledge-links could be the strategy to reach a higher innovative performance appears particularly interesting (Knoblen and Oerlemans, 2012).

⁸As Broström (2010) puts it, the capacity that certain firms can have to offset these costs, and to fine-tune close and distant cooperation along the R&D cycle, would explain the apparent contradictory results which have been found about the non-bounding role of geographical distance for the success of university–industry interaction (Beise and Stahl, 1999; Zucker and Darby, 2001; Scharfetter et al., 2002).

reach the minimum scale to cover the fixed costs, this attempt will not work. For example, a small scale subsidy, or a series of them, which just partially contribute to the costs of extra-regional cooperation, would not affect the decision of the recipient firms to cooperate across the region.

Our argumentation lead, thus, to the following hypothesis:

HP3: Firms' propensity to extend the cooperation with RO beyond the regional borders increases by increasing the amount of R&D subsidy, providing that this latter overcomes a minimum efficient scale

The actual specification of this minimum threshold is of course an empirical issue, specific to both the regional context and the structural features of the regional firms. Our concern for testing this hypothesis is simply that the additionality of the regional subsidy with respect to an extra-regional cooperative behaviour does not appear significant for any (increasing) level of the subsidy, but only above a certain one.

Let us now turn to the hypothesis testing.

3 Empirical application

3.1 Empirical context

The empirical application through which the previous hypotheses are tested refers to the North-East Italy region (NUTS2-level) of Emilia-Romagna (ER).

The region has a population of nearly 4.5 million people and accounts for about 9% of the national GDP (slightly more than 10% of the national industrial production).⁹ The characteristics of its production structure are quite well-know in regional studies. ER has a high density of SMEs, with a pervasive co-location in highly specialised local production systems. ER firms benefit from the diffuse social capital of the industrial districts of the region, a deeply rooted unionism – especially strong in the most industrialised provinces (e.g. Reggio Emilia) – and an articulated institutional set-up of business and research organisations. All these elements have made of the region a successful *milieu*, which has become known as the “Emilian model” (Brusco, 1982).

The region also has a remarkable record in innovation (Antonioli et al., 2011). According to the Regional Innovation Scoreboard (Hollanders et al., 2009), both in 2004 and in 2006, ER is a medium-high innovative region at the EU27 level (the only one in Italy, along with Lombardy). The scoreboard analysis shows that this position is mainly due to a good ranking in the firms' activity indicator, which mainly captures their innovative efforts.¹⁰ On

⁹Our own elaborations drawing on: “Istat - GeoDemo Statistics”; “Istat - Regional Economic Accounts”; “Eurostat - Regional Statistics Database”.

¹⁰Business R&D expenditures as percentage of GDP; non-R&D innovation expenditures; SMEs innovating in-house; SMEs cooperation for innovation; EPO patents per million

the other hand, the weak presence of some innovation enablers¹¹ represents an important innovation drawback of the region. In comparison with other regions in Italy, ER appears closer to those system properties – in particular, the extent of networking activities and clusters – which can be used to identify a RIS (Cooke et al., 1997). However, a study based on the First Community Innovation Survey (Evangelista et al., 2002) has shown that the constitutive linkages of the RIS, both in the business realm and in the science-industry link, turn out to be quite informal and “loosely structured”. The ER RIS thus actually emerges as an “informal learning system”. This picture is confirmed by more recent studies (e.g. Uyarra, 2010), which point to the important role of innovation policy in making the RIS work.

Innovation policy has always been a key-driver in the evolution of the Emilian RIS. Its role has been more pivotal than in other regional contexts (Bianchi and Giordani, 1993). An important instrument in the ER policy-space is represented by the so-called “Regional Programme for Industrial Research, Innovation and Technology Transfer” (PRRIITT), launched for the first time in 2003 (Marzocchi, 2009). This instrument conjugates the attempts of the regional policy-makers to mitigate the weaknesses of the RIS and to exploit the peculiar strengths given by the firms’ dynamism in terms of innovation activities.

The present application makes use of this instrument for testing the hypotheses of Section 2. In particular, we focus on the first two calls (February and September 2004) of the “Measure 3.1 A” included in the PRRIITT. This measure was devised to sustain industrial research and pre-competitive development through more detailed objectives than a general R&D subsidy. Particular important in the scheme is the reinforcement of the collaboration among the components of the RIS, namely between firms and research organisations.¹² With this respect, it is worth stressing that cooperation with ROs (regional and extra-regional), was included among the activities eligible for funding -with higher percentages of public support than other types of expenditures-, but was neither a requirement nor an explicit criterion for the allocation of the policy incentives. Accordingly, this application reveals particularly suitable for testing our hypotheses.

Regional funds were allocated on the basis of the assessment that an independent committee of experts made of the submitted innovation projects.¹³

population.

¹¹Population with tertiary education per 100 population aged 25-64; participation in life-long learning per 100 population aged 25-64; public R&D expenditures as percentage of GDP; broadband access.

¹²Other objectives include: the creation of new R&D employment opportunities, the development of new technologies, and the adoption of intellectual property rights.

¹³The committee evaluated each project along several dimensions (each one with a different total potential score): technical-scientific aspects (45 points); economic-financial aspects (20 points); managerial aspects (20 points); regional impact (15 points). The threshold to get funded was then fixed to 75. The eligible firms were then subsidised by

The overall number of projects subsidised through the two calls was 529, presented by a total of 557 recipient firms. The total cost of the projects proposed by the beneficiaries was about 236 million Euros and the public funding about 96 million, covering around 40% of the total projects' cost. The average regional contribution was of 175,000 Euros per-project.

3.2 Data

In order to test our hypotheses, we rely on a unique dataset. Its starting point is a set of detailed and precise information on the amount and characteristics of the subsidy (PRRIIT measure 3.1 A). By focusing on a single region, we have been able to obtain this information from the regional policy makers. This information has been then integrated with other two firm-level data sources. The first of these is an original Community Innovation Survey (CIS)-kind of survey, carried out in 2009 by [Antonioli et al. \(2011\)](#) on 555 ER manufacturing firms (with at least 20 employees). The second data source is the AIDA-BureauVanDijk database, from which we extracted firms' balance-sheets information.

The CIS-type survey contains detailed information on structural and organisational characteristics of the surveyed firms, and on their innovation strategies. The random sample of 555 firms is stratified by size, province (geographic location at NUTS 3 level) and sector. The information collected mainly refers to the post-policy period: years 2006-2008.

Through balance-sheets, on the other hand, we obtained a number of structural information (e.g. intramural R&D and advertising) for the pre-policy period (year 2003). As we will see in the following, these are used, together with (supposed) time invariant firms' characteristics drawn from the survey, as covariates for the estimation of our econometric models.

After the merging procedure, we were left with a working sample of 408 firms: 99 subsidised, and 309 non-subsidised with the PRIIT Measure 3.1 A. The 99 firms show a distribution by size (SMEs and large firms) and sector (Pavitt/OECD taxonomy) similar to that of all the manufacturing firms (with more than 20 employees) that received the regional R&D subsidy (Table B5).

3.3 Econometric strategy

The strategy we use to test the first two hypotheses (HP1-HP2) is an established one in the recent empirical literature on the impact of R&D subsidies (e.g [Fier et al., 2006](#); [Czarnitzki and Licht, 2006](#); [Busom and Fernández-Ribas, 2008](#); [Fernández-Ribas and Shapira, 2009](#)). Given the

grants covering up to 50% of the total cost of the industrial research activities and up to 25% (35% for SMEs) of the total cost of the precompetitive development activities.

non-exogeneity of the policy support ¹⁴, and the related problems of an OLS model, the estimation of its impact can make use of a *Propensity Score Matching* (*PSM*) approach (Rosenbaum and Rubin, 1983). In brief, the *PSM* tries to get an estimate of the *Average Treatment effect* on the *Treated* (*ATT*) of the policy, defined as:

$$ATT = E(Y_1 - Y_0|D = 1) = E(Y_1|D = 1) - E(Y_0|D = 1) \quad (1)$$

Y_1 and Y_0 denote the value of a certain outcome variable in the presence and absence of the policy (treatment), respectively. D denotes the status of the policy (treatment): $D = 1$, administrated (treated); $D = 0$, non-administrated (non treated).

In Eq.(1), $E(Y_0|D = 1)$ is by definition non-observable. Hence, it needs to be substituted by referring to a suitable “counter-factual” of firms that did not received the policy support. To control for the selection bias (on observables), and make sure that the difference in the outcome of the two groups is exclusively due to the policy intervention, treated firms are matched with non treated ones on the basis of the propensity score, $Pr(D = 1|X)$ (or $P(X)$). This latter represents the probability of being treated given a set of pre-treatment characteristics, X , which are supposed to affect both the treatment and the outcome. In so doing, the *PSM* estimate of *ATT* is given by:

$$ATT_{PSM} = E_{P(X)|D=1} \{E[Y_1|D = 1, P(X)] - E[Y_0|D = 0, P(X)]\} \quad (2)$$

where $P(X)$ is estimated with a probit model.

To estimate Eq(2), we use a set of matching procedures¹⁵, to have an information on the stability and, indirectly, on the reliability of the evidence. These procedures differ in the selection and weightening of the non treated firms to be used as matches, as well as in the capacity to trade between efficiency and bias reduction (Caliendo and Kopeinig, 2008; Smith and Todd, 2005). The common support condition is imposed to all the matching procedures.¹⁶ We finally test the quality of the matching, by controlling that beneficiaries and matched controls are correctly aligned with respect to the vector of the covariates X .¹⁷

¹⁴One just needs to think about the “picking the winner” or the “aiding the poor” strategy with which the R&D subsidy can be devised (Cerulli, 2010).

¹⁵In particular, the 5 nearest-neighbours, the caliper and the kernel, for which see Becker and Ichino (2002); Cameron and Trivedi (2009); Smith and Todd (2005); Caliendo and Kopeinig (2008).

¹⁶This serves to guarantee the presence of suitable counterfactual firms for each treated. In addition to the “minima and maxima” comparison, the 5 nearest-neighbours matching is implemented by imposing the common support condition also with a 1% “trimming” procedure (Caliendo and Kopeinig, 2008).

¹⁷Drawing on Caliendo and Kopeinig (2008), three tests on the quality of the matching

In order to test HP3, an original “continuous treatment” approach is used: the *Generalised Propensity Score* method (*GPS*) (Hirano and Imbens, 2004; Bia and Mattei, 2008). In particular, the *GPS* is here used to estimate, for a set of subsidy levels, the effect of an additional amount of public support.

In technical terms, given the treatment, T , and a set of covariates, X , which explain its administration, the Generalised Propensity Score, R , is defined as (Hirano and Imbens, 2004):

$$R = r(T, X) \tag{3}$$

where the propensity function $r(t, x)$ is the conditional density of the *actual* treatment, t , given the *observed* covariates, x .

Like the propensity score, also the *GPS* has a balancing property.¹⁸ Hirano and Imbens (2004) have demonstrated that, when this balancing propriety is associated with a suitable unconfoundedness assumption, the treatment is unconfounded given the *GPS*. Hence, the *GPS* can be used to eliminate the bias in the estimation of the treatment effect, which is due to differences in the covariates.

Following Hirano and Imbens (2004) and Bia and Mattei (2008), a three-step estimation strategy, illustrated in Appendix A, is employed. Two specific elements of it are however worthwhile clarifying at this stage. First of all, our HP3 refers to the effect of an extra amount of subsidy, on a set of cooperation decisions of discretely increasing geographical distance: no-cooperation, cooperation with a regional partner, and cooperation with an extra-regional partner. Therefore, step-two of the *GPS* strategy is estimated with an ordered probit model. Secondly, the choice of the variation of the treatment, for analysing the incremental effects of the policy, inevitably suffers from *ad-hocness*. In order to reduce it, the characteristics of the investigated context has been considered (Section 3.1). As the average regional contribution was equal to 175,000 Euros, Δt has been heuristically looked for among a set of options and chosen at 20,000 Euros.¹⁹

have been carried out. A first one has checked the reduction, after the matching, of the joint significance of probit model for the propensity score estimation. A second test has checked the reduction, after the matching, of the pseudo-R2 of the probit model. Third, a regression-based t-test on the differences in the covariates means has been run. The results of these tests, available upon request, largely support the quality of the matching procedures.

¹⁸Within strata with the same value of $r(t, x)$, the probability that $T = t$ does not depend on X .

¹⁹This is approximately the cost of an extra temporary contract for a junior researcher in a typical department of a regional university/institute. As a robustness check, we carried out our analysis with different values of Δt , namely 1.00 Euro, 1,000 Euros, and 40,000 Euros.

3.4 Variables

The operationalisation of the previous econometric approach requires us to create two sets of variables. Firstly, a set of suitable covariates, X , need to be included in the estimation of the propensity score and of the GPS . Secondly, we need a set of outcome variables, which capture the impact on the firms' cooperation strategy generated by the receipt of the R&D subsidy (HP1-HP2) and by its amount (HP3).

As for the covariates, these either reflect time-invariant characteristics or are considered at a time (mainly in the year 2003), which is beforehand the policy (administrated in the year 2004). The first two of them control for the most debated specificity factors of the innovation process (e.g. [Malerba, 2002](#); [Cohen, 2010](#)), that is: the firm's *sector* – a set of dummies ($PAVITT1 - PAVITT5$) for its belonging to the Pavitt/OECD sectors – and its *size* – the natural logarithm of the number of its employees ($lnEMP_{2003}$).

A second group of controls tries to account for the intra-RIS heterogeneity in firms' innovation process ([Todtling and Trippl, 2005](#)). This is particularly necessary in the specific case of the ER region given the presence of different industrial districts, which at least partially overlap with its administrative provinces ([Mazzanti et al., 2009](#); [Antonioli et al., 2010](#)). Accordingly, we include a set of dummies ($GEO1 - GEO10$) that capture the firm's location in terms of provinces (NUTS 3-level).

A third group of controls tries to get closer to the pre-policy features of the firms which affect the policy administration. Firstly, their pre-policy expenditure (per capita) in intramural R&D and advertising, $RDADV_{2003}$, is considered as a proxy of their innovative profile.²⁰ Our expectation is that the innovation history of the firm affects its decision to apply for public subsidies. In particular, firms with a high (antecedent) R&D intensity might be willing to use the subsidy to make further steps along their innovation path.

Secondly, the financial condition of the firm is proxied by its cash-flow per capita ($CASHFLOW_{2003}$) and its short-term debt index ($FINCONST_{2003}$). The former accounts for the firm's availability of financial resources to invest in innovation, without recurring to external sources. The latter could instead signal the presence of eventual financial constraints, which prevent firms from investing in R&D.²¹ Our expectation is that the financial barriers of the firms might spur them to apply for the subsidy.

Apart from the sectoral and geographical dummies, all the considered covariates are of a continuous nature. This fact enhances the quality of the

²⁰Unfortunately, disaggregated data for the two kinds of expenditure were not available. On the other hand, recent studies are emerging on their complementary in the current open-innovation and demand-led paradigm (e.g. [Perks et al., 2009](#)).

²¹The short-term debt is here considered to be probably more relevant than the long-term one, given the contingent nature of the decision to plan a R&D project and thus apply for a subsidy.

estimates. Furthermore, nearly all of them are used in the specification of both the propensity score and the GPS. Only few of them had to be dropped to respect the balancing propriety of the latter: the provincial dummies ($GEO1 - GEO10$) and the expenditure in R&D and advertising in year 2003 ($RDADV_{2003}$).

As far as the variables of policy-outcome are concerned, we distinguish between the cooperation with universities and research institutes. This has been done in order to control whether, as some literature suggests (e.g. [Tödtling et al., 2009](#)), the specific type of partner can have a role in channeling the cooperative-additionality of the policy.²² In particular, to test HP1 and HP2 we consider whether in the aftermath of the policy (period 2006-2008), the firms had cooperation agreements in place with: regional universities ($COOPUNI_{REG}$) and research institutes ($COOPRESINS_{REG}$); extra-regional universities ($COOPUNI_{EXTRA}$) and research institutes ($COOPRESINS_{EXTRA}$).

Finally, in order to test HP3, we use two ordinal variables – $COOPUNI_{ORD}$ and $COOPRESINS_{ORD}$ – which, still referring to the post-policy period (2006-2008), account for the geographical range of the interactions between funded firms and ROs. Each of them takes value 0, in case of no cooperation with ROs, respectively; 1, in case of cooperation with at least one regional university or research institute, respectively; 2, in case the firm has cooperated with at least one extra-regional university or research institute, respectively.

Tables [B6](#) and [B7](#) present the main descriptive statistics of the covariates and of the outcome variables we have built up.

4 Results

Before looking at the *PSM* estimates for the first two hypothesis, let us consider the underlying probit estimation (Table [1](#)).

[Table [1](#) around here]

As expected, the R&D support has a higher probability of being searched/received by firms which already have an internal research (and advertising) experience ($RDADV_{2003}$).²³ Similarly, also the sector in which the firms operate is an

²²It should be noted that available data do not allow us to distinguish public from private research institutes. For the private ones, some of the arguments we have used to support our hypotheses might require some adaptations: for example, rivalry and competitive issues might actually emerge with respect to them. Of the spurious nature of this variable we will thus have to take care in the discussion of the relevant results.

²³R&D could equally increase willingness and capacity of firms to apply for the policy. Unfortunately, we cannot distinguish whether previous engagement in R&D increases

important determinant for participation in the subsidy scheme. As expected, firms operating in more dynamic and technology-intensive sectors are more likely to be subsidized. In addition to scale-intensive firms (PAVITT4), science-based companies (PAVITT3) and firms operating in the propulsive district core of the ER region, characterized by specialized suppliers sectors (PAVITT5), have a higher probability of receiving the subsidy. A sound, rather than a weak, financial condition of the firms increases their probability of being funded by the subsidy ($FINCONST_{2003}$ is significantly negative) too. The fact that financial soundness helps firms to show/make a more efficient use of the subsidy is a tentative explanation for this result. The regional policy in this RIS seems to help innovative firms to breed their success in innovation: in brief, a “picking the winner” kind of policy (Cerulli, 2010). This result actually makes necessary to use the econometric methodology we have chosen and to investigate the relative *ATT*.

Table 2 shows that the *ATT* of the policy on the firms’ cooperation with ROs is positive and significant. Funded firms are actually more likely to cooperate with ROs than non-funded ones, irrespectively from the nature of the research partner and from its location. The result is extremely robust across all the four matching procedures employed. HP1 is thus largely supported. The relationship between local firms and ROs actually seems to be affected by costly barriers (e.g. incentive conflicts and resource asymmetries (e.g. Bruneel et al., 2010)), which the policy seems able to attenuate. Within the region, the *ATT* of the policy is higher with respect to universities (from +37.4% to +40.2%) than with respect to research institutes (from +32.8% to +33.5%), while the opposite is true across the regional boundaries (from +13.0% to +19.8%, and from +19.3% to +22.6%, respectively). This is another interesting result. The simple fact of receiving a subsidy of a certain amount spurs firms to increase their collaboration (with respect to the non treated firms) by favoring the search for a more basic kind of knowledge, within the region, and a more applied one, outside of it. In synthesis, the policy actually seems to have added something to cooperative behaviour of regional firms.²⁴ Given the weaknesses the ER RIS in terms of “innovation enablers” (Hollanders et al., 2009), and the lack of those formal, explicit relationships (Evangelista et al., 2002), which are typical of the science-technology link, this result suggests an “illuminated” action by the policy-makers of the region.

[Table 2 around here]

awareness of the need to innovate, and thus the interest/propensity to submit projects, rather than the capacity to present more promising and well-planned proposals.

²⁴A different study on the same sample reinforces this result by looking at other innovative behaviours (Antonioli et al., 2012). In particular, funded firms are more likely (from +16.6% to +20.0%) to report an upgrading in their competencies, when compared to similar non-subsidised companies.

The comparison between the *ATT* of the policy within and across the region largely supports also HP2. With respect to non-funded ones, funded firms are actually more likely to cooperate with regional (from +37.4% to +40.2%) than with extra-regional universities (from +13.0% to +19.8%), and the same holds true for regional and extra-regional research institutes (from +32.8% to +33.5%, and from +19.3% to +22.6%, respectively). This result is also extremely robust and interesting for its implications. On the one hand, it confirms the theoretical hypothesis that ‘geographical-proximity’ could actually favor cooperation with ROs (Boschma, 2005; Ponds et al., 2007). Closer cooperation is actually more handily activable than the distant one by the contribution of the public policy. On the other hand, it remains true that the policy has some additionality in terms of extra-regional cooperation too. Given the role that this kind of relationship plays in opening-up the RIS, by allowing the regional firms to renew the local knowledge base (e.g. Hassink, 2005), this is another very welcomed result of the policy in this RIS.

Let us now consider the test of HP3, which relies on the use of the *GPS*.²⁵

HP3 turns out to be generally supported. Above a threshold of public funding, an increase of the R&D subsidy significantly affects the likelihood of widening the geographical extent of the cooperation with ROs. By considering an increase of 20,000 (40,000) Euros, this threshold is: 200,000 (180,000) Euros, with respect to research institutes (Tables ??) and 180,000 (160,000) Euros, with respect to universities (Tables ??). This is quite interesting, as it supports the argument that research collaborations are affected by up-front, fixed costs, which could create indivisibility problems. In other words, these are costs which can not be compensated by cumulating moderated policy interventions over time, but only with a public funding above a minimum (efficient) scale.²⁶ Although the difference is not large, the minimum efficient scale for cooperating extra-region appears higher with respect to research institutes than universities. In the former case, the collaborative project could entail a more direct application of the results to the business realm than in the latter case (e.g., the exploitation of a certain patent, rather than its obtainment), and the fixed costs could thus be comparatively higher.

Apart from the presence of a minimum efficient scale of public funding, the results are different depending on the nature the partner, but overall still support our HP3. This is confirmed when considering the cooperation with research institutes (Table ??).²⁷ The increase of the policy support above

²⁵Maximum likelihood estimation of the *GPS* is reported in Table B8. In what follows, we report and comment the results obtained with Δt values of 20,000 Euros and 40,000 Euros only. Further comments on the robustness of the test will be added at the end of this section.

²⁶Participating to an international research programme, just to make an extreme example, might require such a high mobility and training costs for the managers (explicit and implicit), to be worthwhile evaluating only if its budget is consistent enough and the public contribution covers it nearly entirely.

²⁷See also the treatment effect functions in Figure B1

the minimum threshold increases the likelihood that the funded firms extend the geographical range of this collaboration across the region ($Y = 2$). With $\Delta t = 20,000$, the range of the treatment effects spans from +6.4% to +14%. The policy could actually help regional firms in using boundary-spanning alliances to overcome the local search for research institutes, by covering the increasing costs of this spanning. To be sure, rather than diminished (if not even ‘overcome’ (Rosenkopf and Almeida, 2003)), the local search is left unaltered by the increase in the policy intervention (i.e., $Y = 1$ is not significantly affected by it).²⁸ In other words, rather than using the policy support for shifting from a local to a global (or simply external) cooperative pattern with research institutes, regional firms appear more inclined to keep the former and possibly make it ‘glo-cal’ (Onsager et al., 2007).

[Table 3 around here]

HP3 does find support also when the interaction with extra-regional universities is considered (Table ??).²⁹ Adding an extra amount of treatment above the threshold enhances the firms’ propensity to cooperate with an extra-regional university ($Y = 2$): in a measure which spans from +5.6% to +20.4%, for an increase of 20,000 Euros. Once more, the policy appears to have a potential role in allowing regional firms to bear the costs of the boundary-spanning exploration of excellent university centres. However, differently from what has emerged for the collaborations with research institutes, the increasing attitude to cooperate with extra-regional academic partners is this time associated to a decreasing propensity to collaborate with a regional university ($Y = 1$). Above the threshold (of 180,000 Euros), an extra amount of subsidy (of 20,000 Euros) induces firms to cooperate less with regional academic partners: from -2.4% to -15.9%.³⁰ This result seems to suggest a sort of substitution effect, between an “inward-looking” and an “outward-looking” cooperation strategy in the case of universities. Its possible explanation can be found in the kind of knowledge which the two types of interactions are likely to generate. Unlike that with research institutes, the cooperation with academic partners is generally carried out within the insitutional grids of internationally codified scientific fields, and with a peer-review system which is also relative more homogeneous geographically.

²⁸Although with a different threshold value (i.e. 180,000 rather than 200,000 Euros), and with a different range of the treatment effects for $Y = 2$ – that is from +9.7% to +30.1% – the results we have obtained for the interaction with research institutes are confirmed for $\Delta t = 40,000$ Euros.

²⁹See also the treatment effect functions reported in Figure B2)

³⁰Once more, these results are robust with respect to the selected Δ of the treatment (i.e. 40,000 Euros), although with a different threshold (160,000 Euros), and different ranges in the effect for $Y = 2$ (from +7% to +39.1%) and for $Y = 1$ (from -8.6% to -32.8%).

Therefore, in the cooperation with local universities, regional firms could find access to an analytical kind of knowledge which is not too dissimilar – at least in terms of breath – from that available outside the regional borders. As a consequence, when, due to the public support, firms have the possibility to deal with the higher cost of a distant cooperation, the collaborations with regional universities are substituted by interactions with extra-regional academic institutes, which probably offer alike, but more qualitatively advanced – in terms of depth – and suitable research capabilities.

[Table 4 around here]

In concluding, we should further note that the obtained results are largely robust across the Δt values that we have selected.³¹ As a further robustness check, we have also tried to carry out our analysis by employing a different type of “treatment”. Instead of the actual amount of the subsidy, we have used the intensity of the subsidy, that is, the ratio between the subsidy and the total amount of the funded project. However, the results show that this is neither particularly meaningful, nor a viable way to proceed in the context of our empirical application. Given also the design of the policy intervention under consideration, which supported the different types of expenditures with fixed percentages, the ratio between the subsidy and the total amount of the project turns out to be extremely concentrated (e.g. the 65% of the observations have a subsidy intensity ratio between 35%-45%). In conclusion, this very low variability made the estimation of the GPS (i.e. the first step of the procedure described in Appendix A) not feasible.

5 Conclusions

The increase of industry-research cooperation represents an important objective to be pursued by the policy makers. Within the region, it strengthens the knowledge-base which becomes available to the local firms for innovating. Across the regional boundaries, it allows them to tap-into different knowledge sources for proposing novel business solutions in the region. A

³¹The evidence emerging from the estimates which employ Δt values of 1.00 Euro and 1,000 Euros has not been illustrated for the sake of parsimony. These additional amounts of subsidy can be considered quite small, when compared to the cost of establishing and managing a cooperation with a research organisation. Accordingly, we could expect that they are not able to have economically meaningful impacts. The results, still available upon request, confirms this point: even if consistent with those presented, in terms of (thresholds of) significance, the treatment effects are indeed very low in terms of magnitude. Tables B9 and B10, which report the standard “marginal effects” of an extra amount of public funding, clearly illustrate this point.

simple instrument like an R&D subsidy appears to be quite effective in both respects.

This is the first important result of the paper. The significant and robust cooperative-additionality revealed by the investigated policy-scheme, suggests us that innovation cooperation is actually affected by costly barriers (López-Martínez et al., 1994; Bruneel et al., 2010). Therefore, the policy maker can have an important role in addressing this failure in the functioning of the RIS.

A further insight emerging from our analysis is the fact that the simple receipt of the subsidy induce local firms to increase their cooperation with ROs more within the region, than across its boundaries. This suggests that, although it can be overcome by relying on other kind of proximities (Boschma, 2005; Breschi and Lissoni, 2009), the geographical distance of the partner still affects the priority that the local firms attach to their cooperative projects. A priority that the simple provision of some contribution to R&D is not able to change.

Moving from this point, our paper has investigated the circumstances under which the public support to R&D activities can stimulate the extension of the geographical range of the cooperation with ROs. Given the presence of indivisible fixed costs that characterise the collaboration with distant research partners,

Our evidence has shown that the amount of subsidy, rather than its simple receipt, is able to affect the geographical range of the cooperation with ROs. Our results suggest that the presence of indivisible fixed costs in extra-regional cooperation, which can be overcome with the contribution of the policy intervention only in case this latter is higher than a certain threshold. Providing the public support is above this minimum threshold, an additional amount of subsidy increases firms' propensity to engage in more costly extra-regional cooperation, through which firms can tap cutting-edge and unique research capabilities. Whether this occurs, or not, at the expenses of a reduction in the propensity to cooperate within the regional borders is another important issue. Quite interestingly, our application shows that the nature of the partner, and of the knowledge which is generated by interacting with it, is a relevant aspect for the eventual shift from an inward (local) to an outward (global) cooperative strategy. These insights have two main implications for policy making. First, investigating which is the minimum scale for extra-regional cooperation to be effective for the local firms, and devise a consistent contribution, becomes an important task for policy makers. Moreover, an accurate screening of the RO through which extra-regional cooperation is expected to provide its gains thus becomes another important policy task.

Of course, the results here presented might be sensible to the characteristics of the context and of the policy considered in the paper: in particular, the fact that SMEs were the main beneficiaries of the intervention, and the

low average public support. Even so, the results of the present study can have some general value in regional studies: despite its idiosyncratic techno-economic characteristics (Brusco, 1982; Hollanders et al., 2009), ER has been found to be a good approximation of the theoretical RIS conceptualisation (e.g. Evangelista et al., 2002) and a benchmark of an industrial-district based model for other countries (e.g. Molina-Morales, 2001; Humphrey, 1995). Furthermore, the same results have been obtained with an original empirical approach. A propensity score matching method, for the analysis of the effects of the participation in the R&D subsidy, has been extended with a generalised propensity score analysis of the impact generated by the increasing amount of public support. At methodological level, this extension has also a general value.

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Covariates	Coeff.	S.E.
<i>lnEMP</i> ₂₀₀₃	0.119	0.083
GEO1	3.420***	1.146
GEO2	1.755*	1.053
GEO3	0.789	1.155
GEO5	1.839*	1.057
GEO6	2.639**	1.096
GEO7	1.531	1.077
GEO8	2.184**	1.083
GEO9	1.849*	1.064
GEO10	1.187	1.122
PAVITT1	0.148	0.29
PAVITT3	1.361***	0.326
PAVITT4	0.575**	0.279
PAVITT5	0.726***	0.255
<i>FINCONST</i> ₂₀₀₃	-0.881*	0.525
<i>CASHFLOW</i> ₂₀₀₃	-0.005	0.005
<i>RDADV</i> ₂₀₀₃	0.162***	0.043
<i>cons</i>	-2.671**	1.219
<hr/>		
<i>N</i> = 408		
Pseudo R^2 = 0.217		
Prob $\geq \chi^2$ 0.000		
<hr/>		
***, **, *: 1%, 5%, 10% significance		
<hr/>		
VIF test excludes multicollinearity		
(all VIF values lower than 10)		
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Table 1: Probit estimation of the propensity score

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
<i>Cooperation with research partners</i>								
<i>Intra-RIS</i>								
<i>COOPUNIREG</i>	0.374***	0.082	0.393***	0.082	0.402***	0.072	0.381***	0.077
<i>COOPRESINSREG</i>	0.335***	0.073	0.335***	0.076	0.330***	0.075	0.328***	0.075
<i>Extra-RIS</i>								
<i>COOPUNIREG</i>	0.189***	0.06	0.130*	0.071	0.138**	0.065	0.198***	0.069
<i>COOPRESINSREG</i>	0.193***	0.074	0.218***	0.075	0.226***	0.075	0.202***	0.077
<i>N treated on support</i>	92		92		92		95	
<i>N treated total</i>	99		99		99		99	
<i>N non treated</i>	309		309		309		309	
Methods:								
5 nearest neighbours (5NN)								
5 nearest neighbours with a 0.05 caliper (Caliper)								
Epanechnikov kernel matching (Kernel)								
5 nearest neighbours with 1% trim (5NN Trim)								
Standard errors estimated with a 200-replication bootstrap procedure								
***, **, *, 1%, 5%, 10% significance								

Table 2: Effect of the subsidy receipt on firms' cooperation with ROs

$(\Delta t = 20000)$	Y = 0			Y = 1			Y = 2		
	Treatment Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000		0.141*	0.078	-0.003	0.064	-0.138	0.108		
80000		0.128	0.087	-0.04	0.045	-0.088	0.07		
100000		0.096	0.068	-0.034	0.034	-0.062	0.045		
120000		0.059	0.047	-0.012	0.017	-0.047	0.037		
140000		0.026	0.029	0.002	0.008	-0.028	0.032		
160000		0	0.017	0	0.008	0	0.023		
180000		-0.022	0.016	-0.01	0.009	0.032	0.02		
200000		-0.042*	0.023	-0.022	0.015	0.064**	0.031		
220000		-0.061**	0.03	-0.032	0.023	0.094**	0.044		
240000		-0.076**	0.037	-0.048	0.036	0.124**	0.057		
250000		-0.080**	0.039	-0.06	0.043	0.140**	0.063		
$(\Delta t = 40000)$	Y = 0			Y = 1			Y = 2		
Treatment Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE	
60000	0.271	0.18	-0.05	0.089	-0.22	0.173			
80000	0.226	0.161	-0.09	0.088	-0.136	0.103			
100000	0.16	0.118	-0.065	0.065	-0.095	0.069			
120000	0.09	0.08	-0.021	0.033	-0.069	0.059			
140000	0.026	0.046	0.002	0.011	-0.028	0.05			
160000	-0.022	0.028	-0.009	0.014	0.031	0.04			
180000	-0.060*	0.034	-0.037	0.029	0.097*	0.056			
200000	-0.093**	0.046	-0.068	0.049	0.161*	0.083			
220000	-0.122**	0.058	-0.097	0.066	0.220**	0.106			
240000	-0.140**	0.067	-0.136	0.083	0.275**	0.123			
250000	-0.140**	0.069	-0.161*	0.089	0.301**	0.128			

Standard errors estimated with a 200-replication bootstrap procedure

***, **, *, 1%, 5%, 10% significance

Critical values of the two sided t-test (df = 100): 10%: 1.660; 5%: 1.984; 1%: 2.626

Table 3: Subsidy-amount effect on cooperation with research institutes

$(\Delta t = 20000)$	Y = 0			Y = 1			Y = 2		
	Treat. Eff.	SE	Level	Treat. Eff.	SE	Level	Treat. Eff.	SE	Level
60000	0.131*	0.07		0.029	0.118		-0.16	0.121	
80000	0.137	0.087		-0.049	0.07		-0.088	0.074	
100000	0.104	0.076		-0.049	0.054		-0.055	0.041	
120000	0.059	0.051		-0.02	0.028		-0.039	0.033	
140000	0.018	0.028		-0.001	0.009		-0.018	0.028	
160000	-0.011	0.014		-0.004	0.008		0.015	0.019	
180000	-0.032**	0.013		-0.024*	0.013		0.056***	0.018	
200000	-0.048**	0.019		-0.052**	0.026		0.100***	0.033	
220000	-0.056**	0.024		-0.088**	0.039		0.144***	0.05	
240000	-0.053**	0.026		-0.134**	0.053		0.187***	0.062	
250000	-0.045*	0.024		-0.159***	0.057		0.204***	0.064	
$(\Delta t = 40000)$	Y = 0			Y = 1			Y = 2		
Treatment Level	Treat. Eff.	SE	Level	Treat. Eff.	SE	Level	Treat. Eff.	SE	Level
60000	0.273*	0.142		-0.031	0.156		-0.242	0.194	
80000	0.25	0.16		-0.121	0.102		-0.129	0.104	
100000	0.172	0.129		-0.093	0.09		-0.08	0.06	
120000	0.082	0.083		-0.03	0.046		-0.052	0.051	
140000	0.005	0.042		0	0.014		-0.005	0.044	
160000	-0.045*	0.024		-0.024	0.019		0.070**	0.034	
180000	-0.075**	0.032		-0.086**	0.041		0.160***	0.054	
200000	-0.091**	0.039		-0.159**	0.068		0.250***	0.085	
220000	-0.094**	0.042		-0.235***	0.088		0.328***	0.106	
240000	-0.077*	0.041		-0.305***	0.097		0.383***	0.108	
250000	-0.063	0.038		-0.328***	0.093		0.391***	0.102	

Standard errors estimated with

a 200-replication bootstrap procedure

***, **, *, 1%, 5%, 10% significance

Critical values of the two sided t-test

(df = 100): 10%: 1.660; 5%: 1.984; 1%: 2.626

Table 4: Subsidy-amount effect on cooperation with universities

A Three-step estimation strategy for GPS

In step one, the conditional distribution of the treatment, T_i , given the covariates, X_i , is estimated, by assuming it – or a suitable transformation of it $g(T_i)$ – normally distributed:

$$g(T_i)|X_i \approx N \{h(\gamma, X_i), \sigma^2\} \quad (4)$$

where $h(\gamma, X_i)$ is a function of the covariates, which depends on a vector of parameters, γ , and g is a logarithmic transformation of the treatment, T .

Estimating the parameters γ and σ^2 by maximum likelihood, the *GPS* for each firm, i , can be obtained as:

$$\hat{R}_i = \frac{1}{\sqrt{2\pi\hat{\sigma}^2}} \exp \left\{ -\frac{1}{2\hat{\sigma}^2} [g(T_i) - h(\hat{\gamma}, X_i)]^2 \right\} \quad (5)$$

With the estimated *GPS*, the normality of $g(T_i)$ and the fulfillment of the assumption on the balancing property can be finally tested.

In step two, in order to “maximise” the joint significance and the goodness of its fit, the conditional expectation of the outcome Y_i , given T_i and R_i , is modelled and estimated as follows:

$$E(Y_i|T_i, R_i) = a_0 + a_1T_i + a_2T_i^2 + a_3R_i \quad (6)$$

The last step of the procedure consists of estimating the treatment effect of an additional amount of subsidy, getting the standard errors through a bootstrapping procedure. Given the parameters estimated in the previous stage, the average potential outcome at level t of treatment is given by:

$$E \left[Y \hat{Y}(t) \right] = \frac{1}{N} \sum_i^n [\hat{a}_0 + \hat{a}_1t + \hat{a}_2t^2 + \hat{a}_3\hat{r}(t, X_i)] \quad (7)$$

The treatment effect for each level of relevant level of the treatment, t , is calculated as the difference between Eq(7), at level $t + \Delta t$, and Eq(7) at t .

B Data appendix

Recipient population distribution	SMEs (< 250 employees) %	Large ($= 250$ employees) %	Total %	Total (<i>a.v.</i>)
Sector				
PAVITT1 (Labour Intensive)	8.55	0.43	8.97	21
PAVITT2 (Resource Intensive)	9.83	2.56	12.39	29
PAVITT3 (Science Based)	11.11	1.28	12.39	29
PAVITT4 (Scale Intensive)	14.96	4.7	19.66	46
PAVITT5 (Specialised Suppliers)	39.74	6.84	46.58	109
<i>Total</i>	84.19	15.81		
<i>Total (a.v.)</i>	197	37		234
Recipient sample distribution				
	SMEs %	Large %	Total %	Total (<i>a.v.</i>)
Sector				
PAVITT1 (Labour Intensive)	9.09	1.01	11.11	11
PAVITT2 (Resource Intensive)	7.07	2.02	9.09	9
PAVITT3 (Science Based)	15.16	1.01	16.16	16
PAVITT4 (Scale Intensive)	14.15	7.07	21.21	21
PAVITT5 (Specialised Suppliers)	34.34	8.08	42.42	42
<i>Total</i>	80.81	19.19		
<i>Total (a.v.)</i>	80	19		99

Table 5: Sample representativeness

<i>Variables</i>	<i>Description</i>	<i>Overall mean (408 obs)</i>	<i>Min</i>	<i>Max</i>	<i>Mean subsidised (99 obs)</i>	<i>Min</i>	<i>Max</i>	<i>Mean not subs. (309 obs)</i>	<i>Min</i>	<i>Max</i>
Time invariant survey data										
Geographical location (10 dummies)	GEO1: Extra-Region GEO2: Bologna GEO3: Forlì Cesena GEO4: Ferrara GEO5: Modena GEO6: Piacenza GEO7: Parma GEO8: Ravenna GEO9: Reggio Emilia GEO10: Rimini		0	1		0	1		0	1
Sector (5 dummies)	PAVITT1: labour intensive PAVITT2: resource intensive PAVITT3: science based PAVITT5: specialised suppliers		0	1		0	1		0	1
Balance sheets data										
$\ln EMP_{2003}$	Log number employees in 2003	4.218	0.693	7.961	4.516	2.639	7.754	4.122	0.693	7.961
$FINCONST_{2003}$	Short-term debt in 2003	0.871	0.32	1	0.838	0.33	1	0.882	0.32	1
$CASHFLOW_{2003}$	Cash-flow p.c. in year 2003 (,000 Euros)	0.792	-1.105	185.222	0.183	-0.475	1.555	0.987	-1.105	185.222
$RDADV_{2003}$	Expend. p.c. in R&D and ADV in 2003 (,000 Euros)	0.007	0	0.405	0.016	0	0.326	0.003	0	0.405

Table 6: Covariates variables

	Overall mean 408 obs	Mean subs. 99 obs	Mean non subs. 309 obs	Min.	Max.
Cooperation with research organizations (ROs)					
Intra-RIS					
<i>COOPUNI_{REG}</i>	0.37	0.717	0.259	0	1
<i>COOPRESINS_{REG}</i>	0.311	0.566	0.229	0	1
Extra-RIS					
<i>COOPUNI_{EXTRA}</i>	0.145	0.343	0.081	0	1
<i>COOPRESINST_{EXTRA}</i>	0.199	0.394	0.136	0	1
Geographical range of cooperation with research organizations (ROs)					
<i>COOPRESINS_{ORD}</i>	0.654	1.192	0.482	0	2
<i>COOPUNI_{ORD}</i>	0.596	1.212	0.398	0	2

Table 7: Outcome variables

Covariates	Coeff.	S.E.
<i>lnEMP₂₀₀₃</i>	0.057*	0.03
PAVITT1	0.203	0.133
PAVITT3	0.210*	0.126
PAVITT4	0.073	0.12
PAVITT5	0.206*	0.111
<i>FINCONST₂₀₀₃</i>	-0.525***	0.182
<i>CASHFLOW₂₀₀₃</i>	0.000	0.003
cons	12.100***	0.221
<hr/>		
$N = 99$		
Pseudo $R^2 = 0.293$		
Prob $\geq \chi^2$ 0.009		
<hr/>		
***, **, *: 1%, 5%, 10% significane		
<hr/>		
VIF test excludes multicollinearity (all VIF values lower than 10)		
<hr/>		
Critical values of the two sided t-test ($df = 100$): 10%: 1.660; 5%: 1.984; 1%: 2.626		
<hr/>		

Table 8: Maximum likelihood estimation of the generalised propensity score

Figure 1: Treatment effect on the cooperation with research institutes. Left: No cooperation with regional partner $Y = 0$, Center: Cooperation with regional partner $Y = 1$, Right: Cooperation with extra-regional partner $Y = 2$. Top: $\Delta t = 20,000$; Bottom: $\Delta t = 40,000$. Confidence bounds at 95% level.

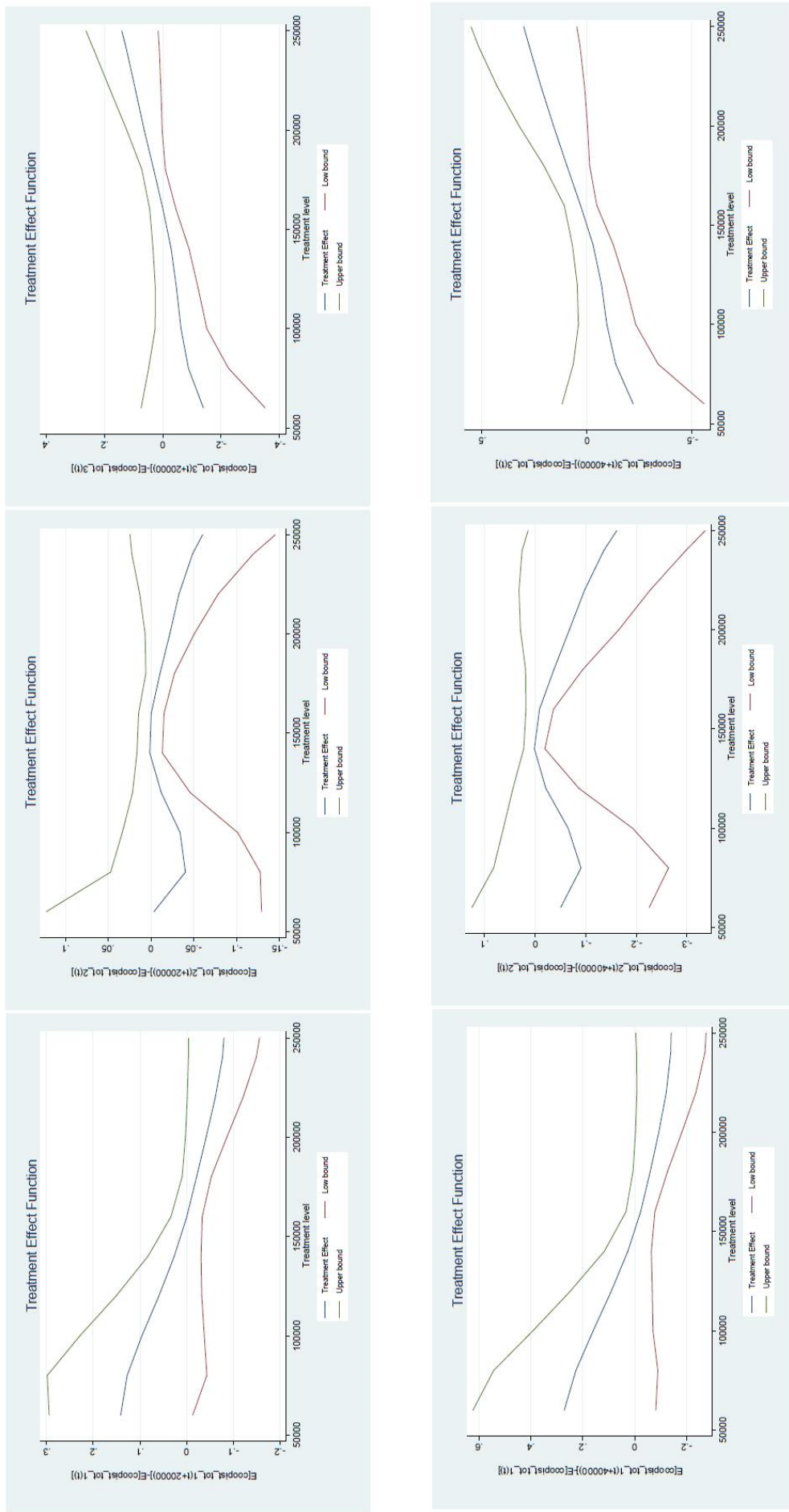
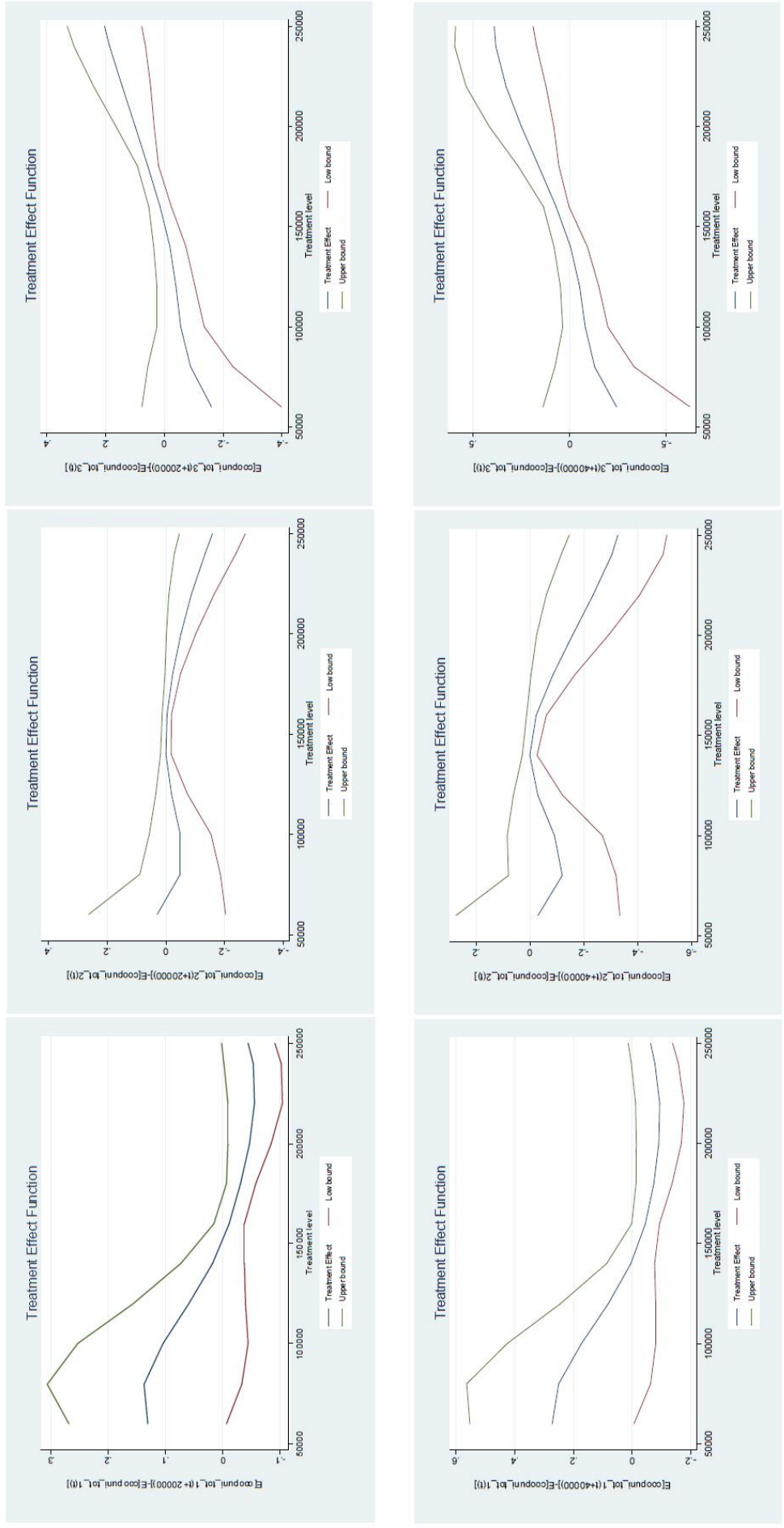


Figure 2: Treatment effect on the cooperation with universities (Left: No cooperation $Y = 0$, Center: Cooperation with regional partner $Y = 1$, Right: Cooperation with extra-regional partner $Y = 2$. Top: $\Delta t = 20,000$; Bottom: $\Delta t = 40,000$. Confidence bounds at 95% level.



$(\Delta t = 1)$	Treatment Level	Y = 0		Y = 1		Y = 2	
		Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000		0.00000679*	0.0000037	0.00000167	0.000004	-0.00000843	0.00000598
80000		0.00000679	0.00000456	-0.00000116	0.00000254	-0.00000565	0.00000451
100000		0.00000545	0.0000039	-0.0000014	0.00000175	-0.00000404	0.00000297
120000		0.00000361	0.0000028	-0.000000447	0.000000976	-0.00000316	0.00000233
140000		0.00000191	0.00000179	0.000000209	0.000000489	-0.00000212	0.00000192
160000		0.000000596	0.00000106	0.000000209	0.000000436	-0.000000775	0.0000014
180000		-0.000000566	0.000000687	-0.000000238	0.000000374	0.000000805	0.00000096
200000		-0.00000173*	0.000000972	-0.000000656	0.000000614	0.00000241**	0.00000124
220000		-0.00000291*	0.00000152	-0.00000101	0.00000093	0.00000039**	0.0000019
240000		-0.00000384*	0.000002	-0.00000143	0.00000139	0.00000528**	0.0000026
250000		-0.00000423*	0.0000022	-0.00000191	0.00000177	0.00000614**	0.00000305

Standard errors estimated with

a 200-replication bootstrap procedure

***, **, *, 1%, 5%, 10% significance

Critical values of the two sided t-test

(df = 100): 10%: 1.660; 5%: 1.984; 1%: 2.626

Table 9: Subsidy-amount “marginal effect” on cooperation with research institutes

$(\Delta t = 1)$ Treatment Level	Y = 0		Y = 1		Y = 2	
	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000	0.0000551**	0.00000274	0.00000483	0.00000626	-0.0000103	0.00000635
80000	0.00000688*	0.00000377	-0.00000775	0.00000457	-0.00000611	0.00000502
100000	0.00000581	0.00000373	-0.00000197	0.0000026	-0.00000386	0.00000295
120000	0.00000373	0.0000027	-0.000000894	0.00000139	-0.0000028	0.00000208
140000	0.00000165	0.00000162	-0.000000000	0.000000609	-0.00000168	0.00000169
160000	0.000000134	0.000000881	-0.000000000	0.000000467	-0.000000179	0.00000123
180000	-0.00000116*	0.000000647	-0.000000596	0.000000628	0.00000176*	0.000000918
200000	-0.00000226*	0.000000999	-0.00000155	0.0000011	0.00000384***	0.00000137
220000	-0.00000311*	0.00000141	-0.00000292*	0.00000169	0.00000599***	0.00000219
240000	-0.00000327*	0.00000156	-0.00000489*	0.00000259	0.00000817***	0.00000306
250000	-0.00000306*	0.00000153	-0.00000635*	0.00000315	0.00000942***	0.00000335

Standard errors estimated with

a 200-replication bootstrap procedure

***, **, *, 1%, 5%, 10% significance

Critical values of the two sided t-test

(df = 100): 10%: 1.660; 5%: 1.984; 1%: 2.626

Table 10: Subsidy-amount “marginal effect” on cooperation with universities