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## Estimating the Local Average Treatment Effect of R&D Subsidies in a Virtual Common Pot

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# Estimating the Local Average Treatment Effect of R&D Subsidies in a Virtual Common Pot

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We investigate the additional effects of *Eurostars*, Europe’s largest multilateral subsidy program for R&D-performing small and medium sized enterprises. A specific budget allocation rule serves as an instrument and allows us to identify the local average treatment effect of public R&D grants. This rule, referred to as Virtual Common Pot (VCP), is designed to avoid cross-subsidization between participating countries. We compare the program’s effect under a VCP with the counterfactual situation under a Real Common Pot (RCP), where project authorities allocate a single budget according to uniform project evaluation criteria. Our estimates suggest a large positive impact on job creation whereas there is no treatment effect on patenting. In addition, we find a relative inefficiency of 19.4% more jobs which could be created by the program under a RCP.

**Key words:** Joint Programming Initiatives, R&D Subsidies, Virtual Common Pot, Instrumental Variable Estimation, Treatment Effect Heterogeneity

**JEL classification:** O38, H25, C31

## 1. INTRODUCTION

Most OECD countries have policy measures in place, either through tax incentives or public subsidies, that aim at providing support for private research and development (R&D) and innovative activities. The rationale for these public interventions lies in prevalent forms of market failure associated with the financing of R&D projects. Limited possibilities to appropriate the returns on R&D investment (Arrow, 1962) and positive economic externalities of knowledge production (Bloom et al., 2013) result in a socially optimal level of R&D investment which exceeds the aggregate investment level of the private sector, also for forms of R&D considered to be “close-to-market”.

Researchers that want to estimate the effects of public R&D subsidy programs face a well-understood endogeneity problem (David et al., 2000). R&D grants are seldom

allocated randomly. Public authorities do not find it desirable to spend taxpayer's money without a careful selection of projects for funding. Usually, applicants have to provide a detailed description of the envisaged R&D activities which are subsequently evaluated on dimensions such as novelty and market potential. Furthermore, firms have to make an active decision to apply for a subsidy program before they can be considered to be assigned research grants by public authorities. This self-selection of firms into a program poses additional difficulties for econometric evaluation methods.

Often, these problems are intensified by limited data availability. It is common practice by public authorities to only publish data on funded projects. Consequently, information about the identity of non-funded applicants of a program is not available to researchers. Project evaluation outcomes are usually confidential as well, which conceals the thorough selection process preceding subsidy allocation. Because of these methodological problems of subsidy evaluation studies, findings on the additionality effects of R&D grants are mixed.

In this paper, we propose a new instrument based on a specific budget allocation rule referred to as Virtual Common Pot (VCP). A VCP represents a solution to the coordination problem that arises when different public entities provide individual financial resources to create a joint subsidy program with a common budget. Policy programs which are part of the initiatives to form a *European Research Area* are particularly exposed to this coordination problem. The member states of the European Union show a desire to integrate their national systems of innovation and scientific research. However, joint programs of R&D support need to comply to the different legal frameworks of State aid within each member state. In addition, there is a challenge to incentivize individual member states to commit sufficiently large budgets to a multilateral program on the expense of their national R&D support schemes.

To avoid free-riding by participating countries and to facilitate compliance with specific national regulations, a VCP combines a joint call and a joint project evaluation with a budget allocation that remains at the national level. This means that the organization of the joint program and the evaluation of applications is delegated to a central authority which creates a quality ranking of all R&D projects proposed by firms. The size of each national financial contribution to the program is agreed on beforehand and each participating country commits to allocate this budget only to their own national applicants but strictly according to the common evaluation ranking.

Such a rule effectively prevents cross-subsidization between countries. As a side effect, it creates variation in the funding status of project proposals which are direct neighbors in the evaluation ranking. Countries are only able to grant subsidies until their respective budgets are exhausted. If there are still sufficient financial resources available for a project proposal which is ranked lower but comes from another country, the proposal still receives funding under the VCP. This is the main difference to a Real Common Pot, where all projects are funded until the common budget is exhausted and from thereon all lower-ranked proposals remain non-funded.

We exploit this variation in funding-status induced by the VCP at a given point in the evaluation ranking as an instrument in a nonparametric instrumental variable estimation.

We estimate the treatment effect of *Eurostars*, the largest multilateral subsidy program for R&D-performing small and medium sized enterprises (SME) in Europe. Eurostars is a *Joint Programming Initiative* of the European Commission and 33 participating countries and organized as a VCP. In the period of 2008 until 2013, the program allocated an estimated total budget of EUR 472 million.

For the region of covariates where the VCP is able to shift funding status we find a substantial positive local average treatment effect on firm growth. Firms funded by Eurostars increase their number of employees by about 2.3 more jobs per year compared to their non-funded counterparts. On the contrary, we find no effect of R&D subsidies on knowledge creation, measured as patenting activities by firms.

We further investigate the inefficiency which arises under a VCP compared to a RCP since budget allocation is not strictly according to project quality. An analysis of treatment effect heterogeneity reveals a positive relationship between treatment effects on employment growth and a project's evaluation rank. We then calculate the counterfactual situation under a RCP by redistributing the program's total budget strictly according to evaluation ranks, thus eliminating the additional national budget constraints in a VCP. Our results suggest that, with the same amount of funding, 19.4% more jobs could be created by the program under an RCP.

These findings contribute to the debate on additionality effects of public R&D grants. In addition, they point to potentially large inefficiencies which arise in the organization of joint programs as a VCP. This is relevant for European policy makers as well as in other settings where there is a need for cooperation between local entities (e.g., states, provinces, or ministries) with budgetary sovereignty and a central authority (e.g., a federal government). The political advantages of a VCP contrast significantly with its economic inefficiency that is the result of treatment effect heterogeneity.

The remainder of the paper is organized as follows. Section 2 introduces the Eurostars program and Section 3 presents the empirical model and describes the data. Results are presented in Section 4. Section 5 provides a discussion of our findings and Section 6 concludes.

## 2. THE EUROSTARS JOINT PROGRAMMING INITIATIVE

Article 185 of the *Treaty on the Functioning of the European Union* enables the EU to coordinate and financially support programs that are jointly undertaken by several member states. These *Joint Programming Initiatives* (JPI) constitute the main policy tool to achieve an integration of the national innovation systems towards a *European Research Area* (ERA).

The *Eurostars Joint Programme* (Eurostars hereafter) was launched in 2008 as a subsidy program for R&D-performing SMEs<sup>1</sup>. Until 2013, the program allocated a total estimated budget of EUR 472 million in ten applications rounds. These applications

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<sup>1</sup>Eurostars defines an R&D-performing SME as a company with less than 250 employees and at least 10% (in full time equivalents) must be employed to conduct R&D activities or at least 10% of annual turnover must be dedicated to R&D (Final Evaluation Report).

deadlines are labeled “cutoffs” in the administrative parlor. The 33 participating countries provided financial resources of EUR 372 million and EUR 100 million were contributed by the *7th Framework Programme for Research and Technological Development* on behalf of the European Commission.

Eurostars is coordinated by EUREKA, a network of European countries<sup>2</sup> which aims at supporting close-to-market R&D for civilian purposes, and its secretariat (ESE) based in Brussels. ESE organizes a joint program call which encourages applications for R&D grants by international project consortia. The main applicant of a project consortium is required to be an SME, however, larger companies and research-based partners such as universities and research institutes are also eligible for funding as part of consortia.

At each cutoff, project proposals are subject to a central evaluation process. Applicants have to provide detailed information about the envisaged R&D activities, work packages, and expected costs. Based on this information, ESE carries out a basic eligibility check regarding administrative requirements. Subsequently, an application undergoes an in-depth analysis by two independent technical experts. These experts rate projects according to three equally important quality criteria

- Basic assessment: the consortium, its participants’ capabilities, the project plan, and financial aspects
- Technology and innovation: the R&D activities to be conducted in the project, the degree of innovation, and the technological profile
- Market and competitiveness: the market opportunities (size, geography, potential, time and risk), return on investment, and strategic importance of the project

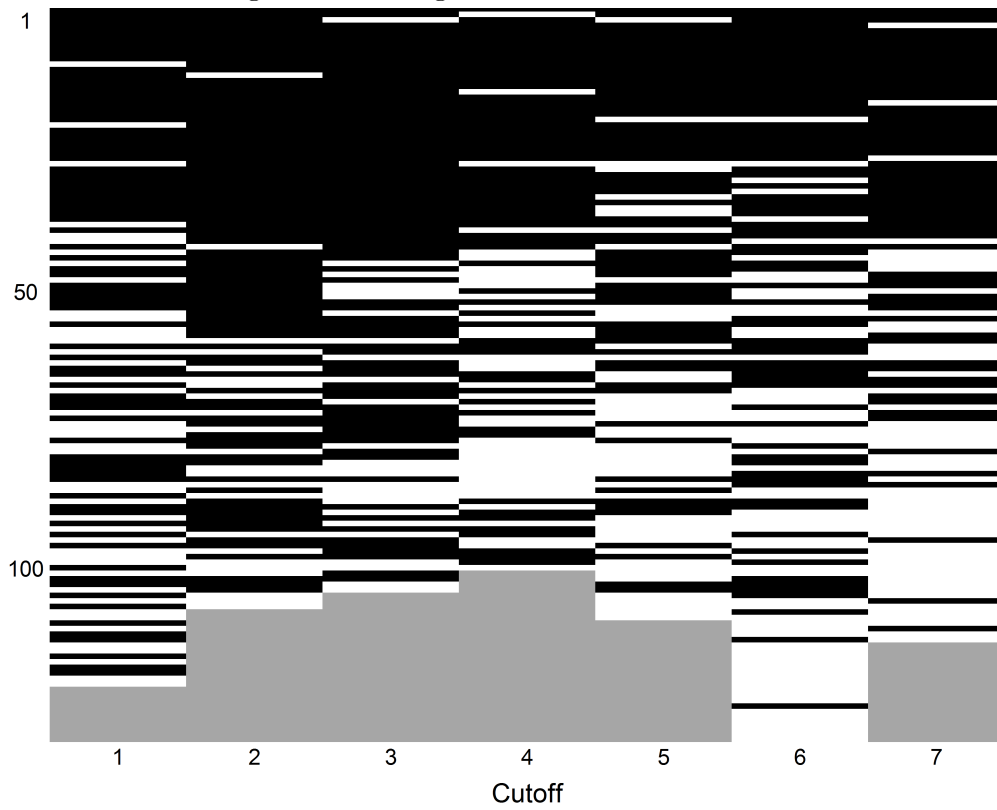
(see Eurostar’s Final Evaluation Report, p. 18 f.). Based on the experts’ reports project proposals are given an overall evaluation score, ranging from 0 to 600. For every cutoff, firms are ranked according to their overall score. Eurostars applies a general quality threshold of a minimum score of 400 below which proposals are not considered eligible for funding.

Participating countries in Eurostars are committed to allocate their earmarked budgets for every cutoff round strictly according to the central evaluation ranking. However, there is no common program budget but rather R&D grants are distributed by every participating country individually to their respective national applicants. Under this allocation rule, referred to as Virtual Common Pot, a project can only receive funding if financial resources are sufficiently available in all countries taking part in the consortium. The additional national budget constraints create variation in the funding of projects with nearly equal evaluation scores as for some projects a budget constraint might be binding whereas for another consortium, due to the geographical distribution of the partners, budget constraints are still slack. This mechanism is also able to create variation in funding status within a country for firms with comparable evaluation scores. Figure 1 gives an impression about the variation in funding at different evaluation ranks introduced by a VCP.

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<sup>2</sup>EU28 and five associated countries: Iceland, Israel, Norway, Switzerland, and Turkey.

Figure 1: Funding in a Virtual Common Pot



*Notes:* Funding status of Eurostars projects according to their evaluation rank in a given cutoff. Black: project is funded, white: project is not funded, grey: no application or applications do not pass the quality threshold.

An analysis of Eurostars and the effects of a VCP on program effectiveness is relevant for other Joint Programming Initiatives by the EU. All large JPIs are organized as a VCP. In addition, the VCP is the dominant budget allocation mode also for smaller ERA initiatives. Around 80% of all joint calls in Europe are organized as a VCP. Although many funded projects were still ongoing, Eurostars was completed in 2013 with the end of cutoff round 10. In 2014, the successor program *Eurostars II* was launched with an even larger budget than the first Eurostars.

### 3. SETUP AND DATA

#### 3.1. Nonparametric Instrumental Variable Estimation

In the presentation of the empirical model we follow the notation in Frölich and Lechner (2014). Let  $Y$  be an outcome variable,  $D$  be a binary treatment variable, and  $Z$  be an instrumental variable. Consider the general model

$$\begin{aligned} Y &= \varphi(D, U_Y, U_{YD}, U_{YZ}, U_{YDZ}) \\ D &= \xi(Z, U_D, U_{YD}, U_{DZ}, U_{YDZ}) \\ Z &= \zeta(U_Z, U_{YZ}, U_{DZ}, U_{YDZ}) \end{aligned} \tag{1}$$

with  $\varphi, \xi, \zeta$  being unknown functions and the  $U$ -variables being mutually independent random variables. This notation makes explicit that there are some influence factors which only affect one variable,  $U_Y, U_D, U_Z$ , some affect two at a time,  $U_{YD}, U_{DZ}, U_{YZ}$ , and there might be factors which have an influence on all variables,  $U_{YDZ}$ .

In the tradition of the potential outcome framework (Rubin, 1974, 1978), we define

$$Y_i^d = \varphi(d, U_{i,Y}, U_{i,YD}, U_{i,YZ}, U_{i,YDZ}), \quad d = 0, 1$$

as individual  $i$ 's potential outcome.  $Y^1$  denotes a treated individual ( $D = 1$ ) and  $Y^0$  a non-treated individual ( $D = 0$ ).

The notion of  $Z$  being an instrumental variable follows from the exclusion restriction that  $Z$  is not an argument of the function  $\varphi$ . Consider the case of a binary instrument,  $Z \in \{0, 1\}$ . Then, there are four possible types  $T$  of individuals in the population depending on the state of  $Z$

$$\begin{aligned} \text{Compliers } (T = c) : & \quad D^{Z=0} = 0 \quad \text{and} \quad D^{Z=1} = 1, \\ \text{Defiers } (T = d) : & \quad D^{Z=0} = 1 \quad \text{and} \quad D^{Z=1} = 0, \\ \text{Always-treated } (T = a) : & \quad D^{Z=0} = 1 \quad \text{and} \quad D^{Z=1} = 1, \\ \text{Never-treated } (T = n) : & \quad D^{Z=0} = 0 \quad \text{and} \quad D^{Z=1} = 0. \end{aligned}$$

If  $U_{YZ}, U_{DZ}$ , and  $U_{YDZ}$  did not exist and  $Z$  would therefore be independent of potential outcomes and types

$$(Y^d, T) \perp\!\!\!\perp Z$$

and for  $\xi$  being monotone increasing in  $Z$ , such that there are no defiers<sup>3</sup>, Imbens and Angrist (1994) show that the local average treatment effect (LATE) for the subpopulation of compliers is identified as

$$E[Y^1 - Y^0 | T = c] = \frac{E[Y|Z = 1] - E[Y|Z = 0]}{E[D|Z = 1] - E[D|Z = 0]}.$$

In the case of Eurostars, we exploit the exhaustion of the respective national budgets for some firms in a project consortium as an instrument. A binding national budget constraint effectively prevents granting treatment to all firms in the consortium. To follow the usual notation that treatment is monotone increasing in the instrument, we define  $Z = 0$  as the case when at least one respective national budget is exhausted and  $Z = 1$  when budget constraints are still slack. Consequently, we have the case of perfect compliance. No project is funded when budget constraints are binding and all applicants receive funding if funds are still sufficiently available<sup>4</sup>. Thus,  $D = Z$  and we can omit the second equation in (1) and the variables  $U_{YD}$ ,  $U_{DZ}$  and  $U_{YDZ}$ . The denominator in the definition of the LATE becomes equal to one and disappears.

Since we acknowledge the possibility that there might be factors  $U_{YZ}$  which appear both in  $\varphi$  and  $\zeta$  and therefore influence outcomes and the instrument, we have to condition on these factors to lend credibility to our instrument. In order to comply with the standard notation in the literature, since we assume  $U_{YZ}$  to be observed, we relabel  $U_{YZ} = X$ . It follows that

$$Y^d \perp\!\!\!\perp Z \mid X.$$

However, this conditioning is only valid under the assumption that the distribution of covariates  $X$  has the same support for both values of the instrument. This assumption makes sure that the treatment propensity lies strictly between zero and one,  $0 < \Pr(Z = 1|X) < 1$  (Heckman et al., 1998). We thus have to restrict our analysis to a region of common support defined as

$$S = \text{Supp}(X|Z = 1) \cap \text{Supp}(X|Z = 0)$$

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<sup>3</sup>Alternatively,  $\xi$  could be monotone decreasing in  $Z$  such that there only exist defiers but no compliers.

<sup>4</sup>A small number of observations in our sample are indicated as “withdrawn” proposals (16 cases in the employment sample) or as “unqualified” or “vetos” (3 cases) by national agencies. This is potentially contradictory to the assumption of perfect compliance as not all projects for which budgets are slack also receive funding. From information provided by program authorities, however, we know that in many cases applicants were encouraged to withdraw their proposals when budgets were exhausted for some firms in the consortium. Projects indicated as withdrawn would therefore be misclassified. In addition, by conditioning on the common support in the matching procedure, we drop projects with very high evaluation scores from the sample. For high scores it is more likely that projects are not withdrawn because of exhausted budgets. Eventually, under the assumption that the few remaining cases of withdrawn proposals and vetos are conditionally independent of potential outcomes, the interpretation of our instrument changes but not its validity. In this case, we define  $Z$  as the combined effect of national budget exhaustion and effects such as subsequent break-up of project consortia or formal problems in the negotiation process for funding.



to be able to make reasonable comparisons between treated and non-treated individuals. Integrating the difference in mean outcomes over  $X$  in the region of common support identifies the average treatment effect for this region

$$E[Y^1 - Y^0|X \in S] = E[Y|Z = 1, X \in S] - E[Y|Z = 0, X \in S].$$

Due to perfect compliance to our instrument, the LATE reduces to an ordinary matching approach. However, our instrument is only able to shift treatment, and thus introduce sufficient variability in funding status, in certain ranges of  $X$ . Most notably, we can estimate the treatment effect of Eurostars funding only for specific regions of the project evaluation score (see Figure 1). Because of this local identification of average treatment conditional on  $X \in S$ , i.e., for a well-defined subpopulation, we present our estimation strategy in the general framework of the LATE (Imbens, 2010).

We employ propensity score matching to alleviate the dimensionality problem (Heckman et al., 1998; Abadie and Imbens, 2012). Rosenbaum and Rubin (1983) establish that the instrument is valid conditional on the one-dimensional propensity score  $\Pr(Z = 1|X) = P(X)$

$$Y^d \perp\!\!\!\perp Z \mid P(X)$$

which we estimate by probit. We match an observation with its nearest neighbor according to the estimated propensity score. Abadie and Imbens (2012) derive the large sample distribution of the propensity score matching estimator. As a side note, we assume that potential outcomes do not depend on the actual treatment exposure. Hence, the assumption of causal effect stability or stable unit treatment values (SUTVA) is fulfilled.

### 3.2. Data

We study the official application data for Eurostars provided by ESE. We restrict the analysis to applications until cutoff round 7, which took place in September 2011, to allow for sufficient time until we evaluate an effect of Eurostars funding. We drop from the sample all non-SMEs which were part of project consortia such as universities, research institutes or larger companies. In addition, we only consider firms from countries which are members of EUREKA and also drop Russia, Ukraine and Malta from the sample. Applications from these countries were very few and Malta only joined Eurostars at cutoff 6. The resulting gross sample includes 3,557 individual firms engaged in 1,786 projects<sup>5</sup>. 978 of these firms received funding, whereas 2,579 did not.

To assess the effect of funding by Eurostars on firm performance, we combine our data set with Bureau van Dijk’s *Amadeus* database and the Worldwide Patent Statistical Database (*PATSTAT*) provided by the European Patent Office. From these sources

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<sup>5</sup>Eurostars allows for resubmissions of proposals as well as submissions of new projects by the same firm in later cutoff rounds. We drop initially unsuccessful applications by firms which received funding at a later cutoff. Subsequently, we only keep the earliest application by a firm in the sample to avoid comparisons of a firm with itself.

we construct variables for the average annual growth in the number of employees (*Employment Growth*) and patents granted to the firm (*Patents Growth*) until 2013. From the respective value in 2013 we subtract the value in the year of the application, which differs according to cutoffs, and divide by the elapsed years

$$\frac{Y_{2013} - Y_{\text{Start}}}{2013 - \text{Start}}.$$

An increased number of employees is indicating firm growth, therefore we see it as a general measure of firm performance. Because we can only identify a subset of the sample firms in Amadeus, we are unable to construct *Employment Growth* for all observations. This is not the case for *Patents Growth* since PATSTAT contains the universe of patents. To avoid incorrect multiple counts of the same invention filed at different patent authorities, we count patent families. We winsorize *Patents Growth* at the 97.5% quantile and *Employment Growth* at the 2.5% and 97.5% quantiles due to outliers which cast doubt about correct figures.

In the estimation we exploit additional information on the technology category of a proposed project (*Technology Class*). Further, we condition on the respective cutoff round of an application. Also, we include the respective value of the dependent variable under study at the time of application (*Employment Start* and *Patents Start*) as a covariate in order to allow for different growth trajectories. Most crucial for identification is the inclusion of project evaluation scores (*Score*) in the propensity score estimation since it directly affects the treatment propensity as well as it has a likely effect on potential outcomes.

Figure 1 shows that the probability to receive funding is close to one for high project evaluation scores because at higher ranks of the *Score* budgets are still slack. This violates the common support assumption introduced in Section 3.1. The same applies for project proposals which do not pass the quality threshold as their treatment propensity is zero by design. We thus restrict our analysis to projects above the quality threshold which have a *Score* less than or equal to 485. We arrive at this value after visual inspection of the treatment propensity distribution over project evaluation scores and justify our choice by graphically analyzing sufficient overlap in Section 4.3.

Eventually, we arrive at estimation samples with 589 observations for *Employment Growth* as dependent variable and 1,176 observations for *Patents Growth*. Table 1 depicts means according to funding status of the variables used in the propensity score estimation. It shows that the inclusion of the previously mentioned covariates in the estimation should help to achieve a better stratification of the data.

Unlike many other studies that evaluate the effects of R&D subsidies, we are able to compare treated and non-treated firms which both applied for funding by Eurostars. Often there is only information available about the identity of treated individuals and a control group needs to be drawn randomly from the population of all firms (possibly conditioning on other observables such as size class, sector, or R&D activity). However, firms make an active decision to apply for R&D subsidies (Takalo et al., 2013). And many firms refrain from ever applying to a program, especially when there are non-negligible application costs involved due to administrative requirements and the need

to coordinate a joint proposal. The subpopulation of applicants for a subsidy program might therefore possess substantially different (unobserved) characteristics. Our data allow us to avoid this problem. As the relevant population underlying our analysis we define all potential applicants to a European Joint Programming Initiative targeted at R&D-performing SMEs.

Table 1: Means of variables according to funding status

	Employment		Patents	
	Funded	Non-Funded	Funded	Non-Funded
Employment Growth	1.47	1.36		
Employment Start	32.52	28.7		
Patents Growth			0.62	0.51
Patents Start			38.34	75.36
Score	447.79	428.71	446.99	428.81
Cutoff				
1	0.17	0.14	0.18	0.21
2	0.14	0.12	0.19	0.14
3	0.19	0.08	0.2	0.11
4	0.09	0.13	0.09	0.1
5	0.11	0.12	0.12	0.1
6	0.17	0.23	0.13	0.19
7	0.12	0.19	0.09	0.15
Technology Class				
1: ICT	0.31	0.27	0.35	0.32
2: Engineering	0.34	0.35	0.3	0.32
3: Bioscience, Pharma and Chemistry	0.23	0.2	0.23	0.2
4: Other	0.13	0.18	0.12	0.16
Observations	393	196	746	430

### 3.3. Instrument Validity

We argue that conditional on the evaluation rank of a firm<sup>6</sup> the availability of sufficient national budget resources to fund a project is independent of potential outcomes. As Figure 1 illustrates, the Virtual Common Pot introduces variation in the funding status for proposals which were evaluated to be of the same overall quality by independent

<sup>6</sup>Or, equivalently, conditional on the project evaluation score and cutoff since ranks are a function of *Score* and *Cutoff*.

technical experts. This is a comfortable situation for the econometrician because it avoids the usual problem of evaluating subsidy schemes which are organized as a Real Common Pot. There, even when the data set contains an indicator of project quality, there is no variability in the funding status of projects with equal quality but at one point where the common budget is exhausted<sup>7</sup>. The availability of budget resources  $Z$  is able to perfectly manipulate funding status  $D$ , which means that there is perfect compliance to our instrument and the distinction between  $Z$  and  $D$  vanishes in the definition of the LATE.

Although countries were able to adjust their budget contributions even after observing the evaluation outcome, they were committed to the allocation rule under the VCP. Thus, there was no room for discretionary treatment of selected firms by national agencies. However, since national budgets vary in their size (relative to demand) the treatment propensity differs for firms from different countries even after controlling for *Scores*. Therefore, the treatment propensity could be correlated with macroeconomic effects at the country levels which affect potential outcomes. To avoid such a potential confounding effect, we condition on a set of country groups in the estimation of the propensity score.

The VCP also introduces variation in treatment within countries. Some firms do not receive funding because national budget of some partners in their consortium are exhausted, whereas for other firms from the same country all budgets might still be slack. Nevertheless, the frequencies of applications for some countries are too low such that we are forced to group countries together. Table 4 in the Appendix depicts two sets of country dummies. The first set is constructed according to a geographical division. To construct the second set we choose a finer division which groups countries according to their average GDP growth in the period of 2008 (year of the first Eurostars cutoff) until 2013. It aims at providing a better approximation to the macroeconomic environment in which firms operate<sup>8</sup>.

The size of our data set does not allow to condition on all possible country compositions of project consortia. Thus, there is room for a potential confounding effect of strategic choice of collaboration partners in order to maximize the probability to receive funding. In the course of the official evaluation of Eurostars on behalf of EUREKA and the European Commission, the expert group in charge conducted an online survey about firms' experience with the program. One item in the survey deals with the question of strategic partner choice. Details about the survey can be found in the final report of the expert group (Final Evaluation Report, 2014). Important for our purposes is, however, that there was a reasonably high response rate by applicants and especially by both,

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<sup>7</sup>In this case, a regression discontinuity design could be employed to identify the LATE at this specific point in the ranking.

<sup>8</sup>The size of national budgets and therefore the commitment to a multilateral R&D subsidy program such as Eurostars, also in relation to existing national programs, depends on various political reasons (see also the Final Evaluation Report, 2014). In addition, it appears that not all countries were successful in forecasting the actual demand for funding. Especially large countries, which are attractive collaboration partners because of, for example, market access, were likely to contribute too small budgets compared to the number of applications. It is therefore not the case that only small countries at the periphery of Europe or countries which were hit particularly hard by the European sovereign debt crisis run out of budget.

Table 2: Matching results

	Employment			Patents		
	(1)	(2)	(3)	(4)	(5)	(6)
$E[Y^1 - Y^0   X \in S]$	0.112 (0.986)	2.349** (1.030)	2.942** (1.393)	0.221 (0.189)	-0.038 (0.171)	0.101 (0.134)
Score	Yes			Yes		
Employment Start	Yes			No		
Patents Start	No			Yes		
Cutoff	Yes			Yes		
Technology Class	Yes			Yes		
Country Dummies	-	1	2	-	1	2
Observations	589	589	587	1176	1176	1176

Standard errors in parentheses: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

funded and non-funded firms.

Respondents were asked to state their opinion about the following statement on a five-point Likert scale

“We chose our project partners strategically from certain countries because we believe that differences in national budgets affect the probability to obtain funding by Eurostars.”

15.4% of firms in our gross sample which were answering the survey agreed with the statement that they chose their project partners specifically from certain countries. 4.2% indicated a strong agreement with the statement. More than 80% of firms had a neutral opinion about the statement, disagreed or disagreed strongly. Other reasons of partner choice, such as technology transfer, access to new markets, or previously existing business relationships were much more important to respondents (Final Evaluation Report, Figure 6-5). In addition, even if firms were aware of the specific allocation rules within a VCP, information about national budgets was not public. Therefore, it is highly questionable whether firms were able to effectively manipulate their chance to obtain funding by strategic partner choice.

## 4. EMPIRICAL RESULTS

### 4.1. Results of the propensity score matching

Table 2 reports results of the propensity score matching. For both outcome variables *Employment Growth* and *Patents Growth* we present three specifications: the first with

no country dummies, a second with *Country Dummies 1*, and a third specification which incorporates *Country Dummies 2*. In the employment estimation with *Country Dummies 2*, one country group (PL and SK) is omitted because it only contains two observations (see Table 4).

Independent of the chosen specification we do not find any positive treatment effect for patents. Point estimates vary around zero and are not near any conventional thresholds of significance. Consequently, we conclude that funding by Eurostars did not affect the patenting activities of firms in our sample.

A different picture emerges in the employment estimation. Although there is no significant treatment effect when country dummies are absent from the estimation, the introduction of *Country Dummies 1* leads to an estimated treatment effect of 2.4%, which is significant at the 5% level. With *Country Dummies 2* the estimated treatment effect even increases to 2.9%, again significant at a 5% confidence level. As we argued earlier, the omission of an appropriate geographical stratification leads to differences in treatment propensities. Table 2 illustrates that these differences introduce a confounding by macroeconomic influence factors which conceal a positive treatment effect in our sample.

Probit estimates of the propensity score are reported in Table 5 and 6 in the Appendix. Significant coefficients show that country and cutoff dummies have an influence on the treatment propensity. By contrast, technology classes are not significant which provides evidence that there is no discrimination according to technological fields in Eurostars. As expected, the project evaluation score affects the treatment propensity positively. Because this variable is crucial in our identification strategy, we also looked at the effect of introducing higher polynomials of *Score* in the probit estimation. Results remained very robust.

#### 4.2. Counterfactual situation under a Real Common Pot

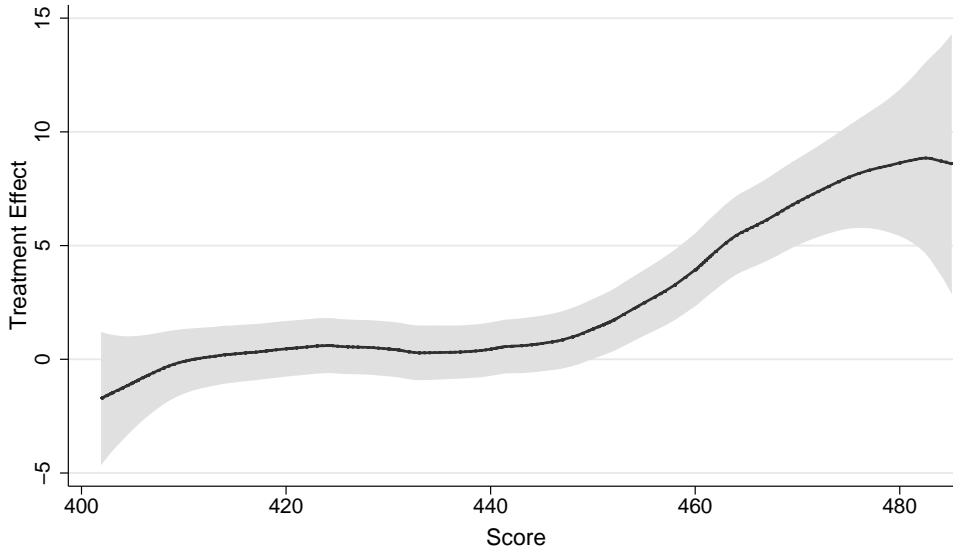
Budget allocation according to a VCP has the effect that R&D grants in Eurostars are not allocated solely on the basis of project evaluations. Instead of one common program budget, several national budget constraints apply. This creates local variation in the funding status and lowers the average project quality of funded projects compared to an RCP. However, whether this effect of a VCP induces an inefficiency depends on the relationship between treatment effects and project quality. If treatment effects are increasing in evaluation ranks, a switch from a VCP to an RCP also increases the aggregate treatment effect and thus the effectiveness of the program.

In the region of common support  $S$ , we are able to estimate the functional form of the expected treatment effects conditional on the *Score*

$$E[Y^1 - Y^0 | \text{Score}, X \in S].$$

By design,  $S$  includes nearly exactly the region of evaluation ranks where a switch from a VCP to an RCP would affect funding status. Although there is a small number of non-funded firms with a *Score* above 485, which we excluded from  $S$  due to insufficient

Figure 2: Treatment effects depending on project scores



*Notes:* Local polynomial regression of treatment effects on project scores. Degree = 1, kernel = epanechnikov, bandwidth = 7.56. Grey area depicts 95% confidence intervals.

overlap, these are only a minority. Most of the firms outside of  $S$  would have received funding under both allocation rules. Thus, we are able to effectively estimate treatment effect heterogeneity in the area relevant for a counterfactual analysis which aims at comparing overall program effectiveness under a VCP versus an RCP.

Since we do not find significant treatment effects for *Patents Growth*, we restrict the counterfactual analysis to *Employment Growth*. As a basis, we take our estimates from column (2) in Table 2. We estimate a local linear nonparametric regression (LLR) of individual treatment effects on *Score* using the Epanechnikov kernel with a bandwidth equal to 7.56, which is found by the rule-of-thumb selection method. To construct confidence intervals, a pilot bandwidth of 11.34 is used. Figure 2 plots the smoothed regression line. There is a large region of project qualities where treatment effects are nearly zero. From a *Score* of around 450 treatment effects then increase quickly up to a peak of around 8.9 created jobs per year. The estimated curve suggest a nearly monotone relationship.

With the help of the LLR we predict treatment effects for all firms in the sample above the quality threshold and with a *Score* less or equal to 485. For these 1,176 observations (equal to the estimation sample for patents) we compute the total grant size per cutoff. We then redistribute this total amount of money spent at every cutoff strictly according to the evaluation ranking, as it would be the case in a RCP. This procedure closes the “gaps” between ranks of funded firms. Starting with the highest rank, all firms receive funding until the common budget for a specific cutoff is exhausted.

For non-funded firms we do not know potential grant sizes but only project costs

Table 3: Counterfactual Analysis of VCP vs. RCP

	VCP	RCP
Number of funded firms	746	796
Total grant size (million €)	177	174
Jobs created until 2013	8,175.35	9,763.72
Grant size per created job (€)	21,660.23	17,841.32

*Notes:* Estimates based on a local linear regression of treatment effects in *Employment Growth* on *Score* in a sample of 1,176 observations.

which they indicated in their application. As an estimate we take the ratio of grant sizes to indicated costs for funded firms and take the average in the gross sample. The resulting average coverage rate amounts to 42.8% which we multiply by the proposed costs of non-funded firms.

We compute the number of created jobs until 2013 as the predicted treatment effect depending on a firm's *Score* multiplied by the number of years from application until 2013. In our sample, 746 firms which are funded by Eurostars under the VCP create a total of 8,175 jobs. The respective total grant size is equal to 177 million euros or 21,660 euros per created job. In the counterfactual situation of an RCP, 796 firms are funded by Eurostars which create 9,764 jobs in total. In this case, the total grant size amounts to 174 million euros, or 17,841 euros per job, with the difference to the actual grant size arising due to the indivisibility of project sizes.

Consequently, the counterfactual allocation of R&D grants within Eurostars according to an RCP creates 19.4% more jobs. This result is not driven by the 50 firms more which receive funding under an RCP. If we impose a coverage rate of 50% of proposed project costs we now find a lower number of funded firms in the RCP compared to a VCP. However, an RCP still creates around 17% more jobs. Table 3 presents the results of the counterfactual analysis in a compact form.

### 4.3. Common Support

In Figure 3 in the Appendix we plot the estimated distributions of propensity scores for both treated and non-treated firms. It shows that both distributions have positive probability mass over nearly the whole unit interval, especially for specifications which incorporate country dummies. For funded firms the distributions have their mode at relatively high treatment propensities which is consistent with the fact that at high ranks of the *Score* the probability to receive treatment is approaching one (see Figure 1). For these regions a LATE is not defined which is why we have to restrict our analysis to a region of common support.

With the chosen region of common support there is substantial overlap in both distributions. In addition, we checked the robustness of our results when applying a trimming



value of  $c = 0.01, 0.02, 0.05$  and omitting observations with estimated propensity scores outside of the interval  $[c, 1 - c]$ , a technique suggested by Crump et al. (2009). Our estimates of average treatment effects and inefficiencies of a VCP are fairly robust towards the introduction of such a trimming.

However, there remains a trade-off. As shown in the previous section, treatment effects become positive in ranges of the *Score* where the propensity to receive treatment is rather high. Choosing a high trimming value  $c$  leads to the exclusion of observations in this region of the covariate support which, in turn, affects estimation results. We believe that our chosen setup together with the conducted robustness checks manage this trade-off reasonably well.

## 5. DISCUSSION

The independent variation in treatment allocation which is induced by the VCP in Eurostars allows us to identify the local average treatment effect of public R&D grants on employment growth and patenting activities of SMEs. On average we find a sizable positive treatment effect on job creation which is increasing in project evaluation scores. However, there is a large region of projects with lower qualities where treatment effects are close to zero. Also for patenting activities we find no additionality effect of public R&D grants.

At first glance, a zero treatment effect of an R&D subsidy program like Eurostars on patent filing is sobering. Public grants are ineffective in stimulating the kind of novel inventions that firms consider to be worth protected by intellectual property rights. However, Eurostars is designed to support and to accelerate the production of new close-to-market products, processes and services. Furthermore, the business development and internationalization of SMEs should be encouraged (Final Evaluation Report, p. 10). This program mission does not directly target the creation of new inventions or knowledge which is measured by a change in the patent stock of a firms. Rather it concentrates efforts on later stages of the innovative process where new knowledge is translated into marketable outcomes.

Moreover, the empirical literature on intellectual property rights generally finds a positive correlation between patenting activity and firm size (Blind et al., 2006). Thus, the focus of our study on small and medium sized enterprises might prevent us from finding a positive treatment effect on knowledge production by, e.g., universities and research institutes in the project consortia funded by Eurostars. Whether the specific requirement of international R&D cooperation creates a division of labor in which private companies appropriate the marketable returns of a project and more research oriented partners contribute new knowledge to the scientific community is an interesting hypothesis but out of the scope of this paper.

Eurostars proves to be effective in stimulating firm growth and job creation. A funded firm in our sample hires on average 2.3 more employees per year (or 2.9, depending on the specification) than their non-funded counterparts. In an unreported analysis, we do not find substantial treatment effect heterogeneity according to cutoffs. We therefore

conclude that the positive employment effect seems to be persistent, at least in the sample period of five years. Comparing the overall grant size with the total amount of jobs created we notice that an amount of around EUR 21,700 is necessary to create a single vacancy. This calculation, however, does only take the size of R&D grants into account which were directly distributed to firms. It disregards the substantial administrative costs of a joint program like Eurostars. Therefore, the actual value-for-money ratio for public authorities is likely to be lower than our results suggest.

The sizable treatment effect we find for employment growth illustrates a selection into subsidy programs by firms. There are non-negligible costs of applying and dealing with the administrative burden in the negotiation process between firms and public authorities. We can expect that only firms for which the positive effect of a subsidy exceeds these costs actually apply. A control group from the population of all SMEs is therefore likely to not be the right benchmark for comparison, as not all firms in the population could be encouraged to apply for R&D grants.

Furthermore, we see two main reasons why the particular design of Eurostars contributes to a large treatment effect in employment growth. First, the mean of employment growth in our sample is around 1.44 with a standard deviation of 6.46. There is a sizable fraction of around 25% of firms which exhibit negative growth rates. The compound annual growth rate in GDP of the countries in our sample between 2008 until 2013 amounts to -0.002. In a macroeconomic environment of recession, public support proves to be effective in shielding firms from the need for drastic economic adjustments. Thus, the large positive treatment effect we find is partly stemming from the preservation of jobs rather than exclusively from positive firm growth. Second, the focus of the European *Joint Programming Initiatives* to encourage international R&D cooperations is favorable for job creation. In Eurostars, SMEs are required to be the main applicant in a consortium. It is likely that they are also mainly responsible for the organization and management of project consortia. Such a task demands a considerable amount of human resources. Again, we can expect that only firms for which the benefits of a subsidy outweigh the additional costs of labor appear in the pool of applicants.

The instrumental variable approach we pursue poses questions about the external validity of our results. We are only able to provide valid estimates of the local treatment effects in regions of the covariate support where our instrument has the power to manipulate funding status. This is specifically related to a certain country composition in the region of common support. Furthermore, we are completely agnostic about the size and sign of treatment effects in certain regions of the evaluation ranking.

As we argued earlier, the reasons why countries within Eurostars run out of budget are not unidimensional and also not constant over time. There is no systematic pattern present, such as, that national budgets of small countries with a below average GDP are exhausted the earliest. Instead, large countries often provide too few resources compared to the demand they face. Also, actual demand is difficult to forecast, as it varies over time. Consequently, our instrument is powerful enough to manipulate treatment status over a wide support of the geographical distribution in the sample.

We restrict our analysis to project above the quality threshold and with evaluation

scores not exceeding 485. Within this range we find a monotone increasing relationship between scores and treatment effect. This does not need to hold for the entire support of scores in the sample. However, the large region of scores, up until around 450, for which confidence bands include the zero suggest that treatment effects below the quality threshold of 400 are also near zero. On the other end of the distribution treatment effects do not necessarily need to stay high. Firms with projects of very high quality are more likely to be able to substitute public funding with financing from other sources. Treatment effects might therefore level off at some point in the ranking<sup>9</sup>.

In the range of evaluation ranks where our instrument shifts funding status, i.e., the region where a switch from a VCP to an RCP changes the composition of funded firms, the positive relationship between scores and treatment effects determines the inefficiency introduced by a VCP. If treatment effects were homogeneous, a shift to an RCP, which increases the average quality of funded projects, would not result in higher aggregate treatment effects. In our case, we find a steep increase of treatment effects for high evaluation scores which translates into a substantial inefficiency of 19.4%.

The heterogeneity in treatment effects poses a serious challenge for policy makers as the functional form of the expected treatment effect conditional on evaluation scores is not known *ex ante*. Eurostars applies a minimum score of 400 as a quality threshold. However, our estimates show that this threshold is not effective in selecting projects with a positive treatment effect on employment growth. Only at a score of around 450 treatment effects become positive. Policy makers still have very limited theoretical guidance about the determinants of positive treatment effects on firm growth. Furthermore, the conditional expectation function depends on program specific quality evaluation criteria. For other subsidy programs, public authorities might face a very different curve which is why general guidelines do not apply.

## 6. CONCLUSION

We presented a nonparametric instrumental variable estimation of the output additionality of public R&D grants. We studied the effect of Eurostars, a large-scale, European-wide subsidy program for SMEs which is organized as a Virtual Common Pot. The VCP is a specific budget allocation rule designed to avoid cross-subsidization between participating countries. It creates independent variation in the treatment propensity that can be exploited as an instrument. Because of perfect compliance to our instrument, the estimation of the local average treatment effect reduces to a selection-on-observables problem which we tackled by propensity score matching.

We did not find a positive effect of the program on knowledge creation, measured as the patent stock of a firm. However, the design of Eurostars as a subsidy program supporting SMEs in conducting close-to-market research is not particularly targeted at

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<sup>9</sup>This discussion does not concern the possibility of systematic inaccurate quality assessment by technical experts. The objective of the project evaluation process is to rank proposals according to innovativeness, technical feasibility, and market potential. These criteria are not equivalent to a positive treatment effect for funded projects which is difficult to assess *ex ante*.

promoting new inventions. By contrast, we found a sizable treatment effect on firm growth, measured as employment growth.

Our analysis is limited to a subset of outcome variables which could possibly be affected by public R&D grants. Unfortunately, information about R&D expenditures by firms is very scarce in the Amadeus database used in this paper. We thus can not contribute to a strain of the literature which is concerned with the input additionality of subsidy programs. We are also not able to assess the effect of Eurostars on patent measures like the citation weighted patent stock of firms because our data are too recent. In addition, because we observe firms in our sample for a maximum period of five years after grant application the longterm consequences of R&D grants remain unexplored. These topics are left for future research.

In an investigation of treatment effect heterogeneity, we found a positive relationship between project evaluation scores, assigned by independent technical experts, and treatment effects on firm growth. Due to lower average project quality, because of additional national budget constraints, a VCP introduces a relative inefficiency of 19.4% compared to a Real Common Pot, the traditional allocation of a single program budget. A VCP is able to solve the coordination problem which arises in joint policy programs by entities with individual budgetary sovereignty but only at the cost of a severe penalty on program effectiveness.

Moreover, we encountered a large region of project scores where treatment effects are nearly zero. Although projects in this region are generally ranked lower they still are considered to meet the quality threshold of Eurostars and are thus eligible for treatment. This illustrates the fact that a quality assessment by technical experts according to criteria such as technical feasibility and market potential of innovation projects does not necessarily coincide with positive treatment effects in comparison with non-funded firms. This complicates the task of policy makers who are concerned with maximizing the additionality effect of public R&D subsidy programs on firm growth and competitiveness.

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APPENDIX

Table 4: Country Groups

	Employment	Patents	
<hr/>			
Country Dummies 1			
DE	105	156	
FR	26	121	
IT	45	67	
UK, IE	15	93	
NL, BE, LU	73	99	
AT, CH	39	79	
FI, SE, NO, DK, IS	94	214	
GR, PT, ES	125	185	
EU since 2004	67	113	
Other	0	49	
<hr/>			
Country Dummies 2			Avrg. GDP Growth
DE	105	156	0.66
FR	26	121	0.16
IT	45	67	-1.54
UK	12	81	-0.12
NL, BE, LU, AT	84	138	-0.22
EE, LV, LT	16	28	-0.2
SE, NO	68	127	1.18
GR, PT, ES, IE, CY	128	204	-2.17
FI, DK, IS	26	87	-0.81
CH, TR, IL	28	89	3.1
PL, SK	2	14	3.1
CZ, RO	27	32	-0.48
SI, HR, HU	22	32	-1.73
<hr/>			
Observations	589	1176	
<hr/>			

*Notes:* Frequencies in the estimation samples. Average GDP Growth between 2008 and 2013 is calculated as  $(GDP_{2013} - GDP_{2008})/5$  and averaged within a group. GDP is measured as an index with 2005 = 100. Source: Eurostat (September 2014).

EU since 2004: BG, CZ, CY, EE, HR, HU, LV, LT, PL, RO, SI, and SK

Table 5: Probit estimates (employment)

	(1)		(2)		(3)	
Score	0.023***	(0.003)	0.028***	(0.003)	0.028***	(0.003)
Employment Start	0.000	(0.001)	0.000	(0.001)	0.001	(0.001)
Cutoff 1	0.362*	(0.207)	0.321	(0.222)	0.429*	(0.225)
Cutoff 2	0.290	(0.219)	0.271	(0.229)	0.369	(0.234)
Cutoff 3	0.860***	(0.227)	0.854***	(0.237)	0.934***	(0.240)
Cutoff 4	0.056	(0.228)	0.070	(0.237)	0.251	(0.244)
Cutoff 5	0.537**	(0.228)	0.586**	(0.241)	0.590**	(0.242)
Cutoff 6	0.127	(0.199)	0.052	(0.212)	0.060	(0.215)
Technology Class 1	0.211	(0.185)	0.146	(0.191)	0.178	(0.193)
Technology Class 2	0.092	(0.180)	0.037	(0.188)	0.098	(0.191)
Technology Class 3	0.040	(0.194)	-0.007	(0.202)	0.051	(0.206)
Constant	-10.136***	(1.152)	-11.802***	(1.255)	-11.470***	(1.282)
Country Dummies 1						
DE			-0.966***	(0.230)		
FR			-0.247	(0.331)		
IT			0.144	(0.298)		
UK, IE			-1.111***	(0.412)		
NL, BE, LU			-0.720***	(0.244)		
AT, CH			0.463	(0.347)		
FI, SE, NO, DK, IS			-0.594**	(0.234)		
GR, PT, ES			-0.205	(0.216)		
EU since 2004						
Other			Omitted			
Country Dummies 2						
DE					-1.409***	(0.360)
FR					-0.662	(0.431)
IT					-0.273	(0.405)
UK					-1.526***	(0.544)
NL, BE, LU, AT					-1.054***	(0.362)
EE, LV, LT					-0.895*	(0.468)
SE, NO					-1.120***	(0.373)
GR, PT, ES, IE, CY					-0.650*	(0.346)
FI, DK, IS					-0.755*	(0.434)
CH, TR, IL					0.369	(0.532)
PL, SK					Omitted	
CZ, RO					-0.267	(0.423)
SI, HR, HU						
Observations	589		589		587	

Standard errors in parentheses: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ 

Dependent variable: Funding

Table 6: Probit estimates (patents)

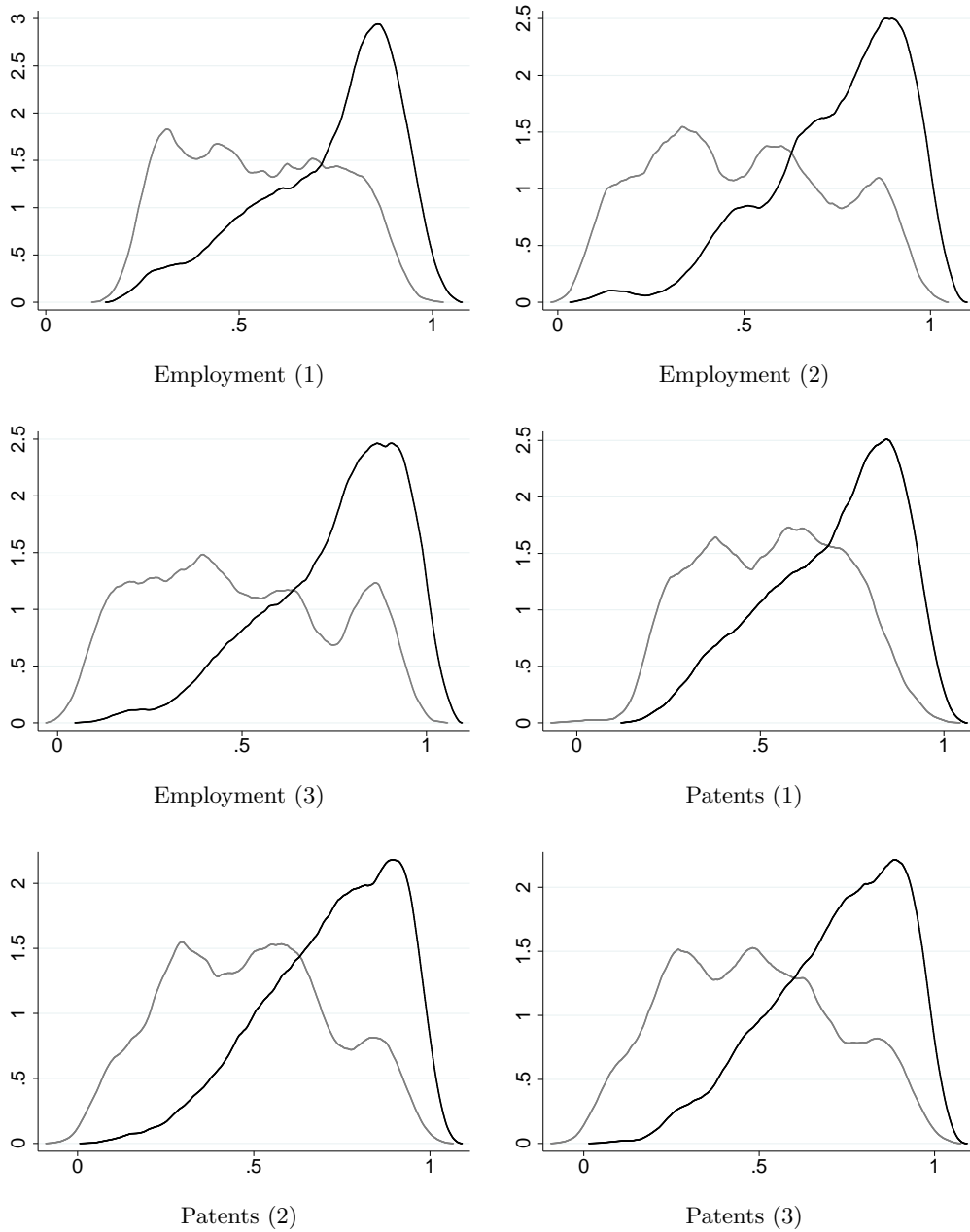
	(1)		(2)		(3)	
Score	0.023***	(0.002)	0.026***	(0.002)	0.027***	(0.002)
Patents Start	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
Cutoff 1	0.265*	(0.148)	0.193	(0.155)	0.204	(0.155)
Cutoff 2	0.451***	(0.155)	0.460***	(0.159)	0.495***	(0.160)
Cutoff 3	0.814***	(0.158)	0.863***	(0.164)	0.856***	(0.162)
Cutoff 4	0.387**	(0.174)	0.398**	(0.179)	0.476***	(0.181)
Cutoff 5	0.721***	(0.172)	0.762***	(0.178)	0.764***	(0.179)
Cutoff 6	0.114	(0.155)	0.038	(0.161)	0.033	(0.161)
Technology Class 1	0.169	(0.130)	0.114	(0.134)	0.124	(0.135)
Technology Class 2	0.120	(0.131)	0.103	(0.135)	0.107	(0.136)
Technology Class 3	0.101	(0.138)	0.085	(0.142)	0.101	(0.143)
Constant	-10.031***	(0.806)	-11.191***	(0.857)	-11.118***	(0.877)
Country Dummies 1						
DE			-1.060***	(0.177)		
FR			-0.114	(0.184)		
IT			-0.138	(0.220)		
UK, IE			-0.900***	(0.195)		
NL, BE, LU			-0.777***	(0.193)		
AT, CH			0.037	(0.215)		
FI, SE, NO, DK, IS			-0.404**	(0.164)		
GR, PT, ES			-0.036	(0.167)		
EU since 2004						
Other			-0.379	(0.232)		
Country Dummies 2						
DE					-1.352***	(0.277)
FR					-0.396	(0.281)
IT					-0.420	(0.305)
UK					-1.224***	(0.293)
NL, BE, LU, AT					-0.987***	(0.277)
EE, LV, LT					-0.646*	(0.350)
SE, NO					-0.778***	(0.280)
GR, PT, ES, IE, CY					-0.377	(0.267)
FI, DK, IS					-0.560*	(0.293)
CH, TR, IL					-0.266	(0.292)
PL, SK					-0.732*	(0.441)
CZ, RO					0.125	(0.353)
SI, HR, HU						
Observations	1176		1176		1176	

Standard errors in parentheses: \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ 

Dependent variable: Funding



Figure 3: Estimated propensity scores



*Notes:* Kernel estimates of the propensity scores for the respective matching to assess the common support assumption. Black line: density of the predicted probability that a funded firm is assigned to funding ( $f_{P,D=1}$ ), grey line: density of the predicted probability that a non-funded firm is assigned to funding ( $f_{P,D=0}$ ). Bandwidth = 0.1, kernel = triangle.