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Absorptive capacity and the delocalisation of university-industry interaction

Evidence from participations in the EU's Sixth Framework Programme for Research

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Abstract

Increasing university-industry interaction and university contribution to the local economy are compatible –conventional wisdom would say. However, as other university activities, interaction with industry may be limited due to a lack of absorptive capacity in local firms. We exploit data on participations to EU 6th R&D Framework Programme (FP6) to generate measures on the number and, notably, the budgets of UII projects at regional level for the EU27. Our analysis indicates that universities from regions with low absorptive capacity participate more often in FP6 projects with firms outside the region. Our results highlight the value of policies that facilitate firm R&D to enhance collaboration with regional universities.

Resumen

Aumentar la interacción universidad-empresa (IUE) y la contribución de las universidades a la economía local es compatible –diría la sabiduría convencional. Sin embargo, al igual que otras actividades universitarias, la interacción con la empresa puede ser limitada debido a una falta de capacidad de absorción de las empresas locales. En este artículo se explota datos sobre participación en el 6º Programa Marco (PM6) de I+D para generar medidas del número y, destacablemente, del presupuesto de los proyectos con IUE a escala regional en la UE27. Los análisis indican que las universidades de regiones con baja capacidad de absorción participan más a menudo en proyectos del PM6 con empresas de fuera de la región. Los resultados enfatizan el valor de las políticas que faciliten la I+D de las empresas para impulsar la colaboración con las universidades regionales.

Laburpena

Unibertsitatearen eta enpresaren arteko elkarreragina areagotzea eta unibertsitateek tokiko ekonomiari laguntzea bateragarriak dira –esango luke herriko jakinduriak. Baina, unibertsitateko beste jarduera batzuetan gertatzen den bezala, honen eta enpresaren arteko elkarreragina mugatua izan daiteke, tokiko enpresei bereganatze ahalmena falta zaielako. Artikulu honetan I+Gko 6. Programa Markoan parte hartzeari buruzko datuak ustiatu ditugu, EB-27ko eskualdeetan unibertsitatearen eta enpresaren arteko elkarreraginean oinarritzen diren proiektuen kopurua eta, batez ere, aurrekontua, neurtzeko. Azterlanak erakusten digu bereganatze ahalmen txikia duten eskualdeetako unibertsitateek 6. Programa Markoko proiektuetan nagusiki eskualdeaz kanpoko enpresekin hartzen dutela parte. Emaitzek enpresen eta eskualdeko unibertsitateen arteko lankidetza ahalbidetuko duten I+Gko proiektuen balioa azpimarratzen dute.

1. Introduction

University-industry interaction (UII) has increased in most developed countries over the last 30 years or so, due to changes in societal demands and institutional changes that have redefined the needs of universities for funding. Many approaches to the study of innovation have advanced our understanding of the potential benefits arising from increases in UII (Lundvall, 1988, Gibbons et al., 1994, Etzkowitz and Leydesdorff, 1996). Others have been more sceptical of excessive UII: First of all, there is the danger of what Mokyr (2002) describes as an expansion of prescriptive knowledge at the expense of propositional knowledge – essentially diverting university-based R&D away from deeper scientific understanding and towards technological development – with long term repercussions for economic welfare. Second, there are questions about the compatibility of channelling this interaction through commercialisation mechanisms or a wider range of instruments (David and Metcalfe, 2007). Until now, these arguments have been posed either within strictly defined regional boundaries (e.g. at the level of specific countries or regions) or without an explicit regional focus, with some empirical evidence on the complementarities between scientific productivity and UII (e.g. Manjarrés et al., 2008). However, in the context of the increasing de-localisation of knowledge flows, a by-product of economic globalisation and the tendency towards the increasing codification of knowledge (Malmberg and Maskell, 1997), it is fair to ask whether UII is also subject to particular regional patterns and subsequent trade-offs. This could be the case, given that UII is an international activity, requiring resources that can compete at that level, which poorer countries or regions may not have (Geoghegan and Pontikakis, 2008).

In the field of innovation studies, most regional concerns come from the innovation systems literature focusing on the capacity of regions (Cooke, 1992) to fully or partially design their R&D policies, often with a special reliance on UII as a motor of local economic development (Oughton et al., 2002). Although regions are recognised as a relevant unit of analysis on UII, there is less systematic comparison of differences among regions than among countries, and by extension a rather shallow understanding of the reasons behind such differences.

What are the reasons behind such differences? Absorptive capacity is a very powerful explanatory variable of innovative success at the firm level (Cohen and Levinthal, 1989). Transposing this insight at the level of regions -assuming in other words, that the concept of absorptive capacity can be applied more broadly than the firm setting-, it is worth asking whether differences in absorptive capacity may condition the localisation of UII.

In this paper, we attempt to cover the aforementioned gaps in the literature through the study of the differences between localised (intraregional) and delocalised (interregional) UII, the measurement of the phenomenon by looking at the quantity and value of interactions, the breakdown at regional level and a theoretical and empirical explanation of observed variations.

2. Building a hypothesis about the relation between localisation of university-industry interaction and regional absorptive capacity

The aim of this section is to tackle the intersections among the three strands of literature involved in the paper: university-industry interaction (UII), regional innovation systems and absorptive capacity.

2.1. Higher absorptive capacity increases university-industry interaction

The concept of firms' absorptive capacity attempted to explain how firms are able to benefit from R&D spillovers. University-industry interaction is different from R&D spillovers because the former involves engagement into partnerships, increasingly through contractual arrangements. The theoretical relation between firms' interaction with universities and absorptive capacity is then not obvious.[1]

However, high absorptive capacity is an explanation of, for example, why German firms maintain long-standing links with universities and vice-versa: the knowledge flows are bi-directional so universities also get relevant knowledge from firms (Meyer-Krahmer and Schmoch, 1998).

Some statistical and econometric works support this idea. Mangematin and Nesta (1999) find some empirical evidence in favour that firms involved in projects with the French National Centre for Scientific Research (CNRS) benefit from a larger amount or cooperation and a wider range of modalities of research (not only applied and tacit but also fundamental and codified) if their absorptive capacity is higher. Fontana et al. (2006) corroborate, for seven EU countries, that R&D intensity, the usual proxy for firm absorptive capacity, has a significant influence on the number of R&D projects with PROs (including universities). Laursen and Salter (2004) find a similar positive relation between R&D intensity and an ordinal value of the use of knowledge created in universities by firms in the UK sample of the Eurostat Community Innovation Survey (CIS)[2]. Alegre and Chiva (2008) find that firm interaction with the external environment, including universities, positively correlates with the degree of organisational learning capability (OLC) in the Spanish and Italian ceramic tile industry –being OLC a concept concomitant with that of absorptive capacity.

2.2. Regions differ in their degree of absorptive capacity

The concept of absorptive capacity has traditionally focused on firms, but in recent times, some analysts have applied it to the context of regions, talking about 'regional absorptive capacity'.

Among the first authors to talk about 'regional absorptive capacity' as such, Niosi and Bellon (2002) apply the analogy of the twin purpose of firm R&D to regions and state that regional R&D not only produces knowledge but also places the region in a better position to incorporate externally generated knowledge. They distinguish five components in the learning process through which regions improve this latter capacity: human capital, organisations and institutions, investments in R&D, industrial structure and some so-called 'sequences'. As the authors argue, these sequences are path-dependent, starting with the creation of an 'engine' organisation that interacts with policy incentives. In successful processes, public intervention contributes to regional absorptive capacity. However, the authors highlight that 'human capital is the basic building block of regional absorptive capacity […] An expansion of the regional stock of human capital

[1] The management literature has nevertheless paid attention on how firms can increase the success of interaction with universities, with recommendations that could perfectly fit in the concept of raising absorptive capacity, like the creation of hybrid organisations (Andrisano et al., 2006, Rohrbeck and Arnold, 2006) or coping with the different available instruments for interaction (Romero, 2007).

[2] These authors sometimes refer to the 'use of knowledge created in universities' as a proxy for university-industry interaction in the sense that we give it here: partnerships, not spillovers. However, it is not clear from the nature of their dependent variable whether it excludes spillovers.

across the board will be required, and in particular an increase in the stock of industry-specific human capital' (p.20).

Adopting the perspective of regional innovation systems (RIS), Vang and Anshem (2006) are more interested in investigating the importance of regional absorptive capacity for the region's strategic coupling with transnational corporations (TNCs), in the sense that regional absorptive capacity can contribute to avoiding situations where TNCs become 'cathedrals in the desert'. For the authors, the concept of regional absorptive capacity is crucial in understanding the knowledge transfer process between the TNCs and the 'local' firms and subsequently the spillovers into the regional economy (in this case building of high-tech regions). The concept needs to supplement the more traditional ingredients in theorising strategic coupling, which appear too centred on the focal firms and more concerned with bargaining powers. As the authors state,

> *"in RIS we suggest that (a) a firm's absorptive capacity is a function of its prior internal knowledge—being tacit or codified—and the institutional setting (referring to among other aspects how social capital allows for knowledge to circulate and how public institutions serve this knowledge circulation) and its interactive learning based collaboration with other knowledge sources; and, (b) that a region has an absorptive capacity (which is a function of the individual firm's absorptive capacity, human capital (formal and tacit) and social capital[3])."*

A first insight to the possibility that lower regional absorptive capacity has a link with higher internationalisation of R&D activities is the reflection of Zabala et al. (2007). They argue that territories with lower absorptive capacity and fewer resources adopt the embodied knowledge and the innovations of others, which are less risky and involves lower levels of development; traditional sectors rapidly and efficiently adopt this 'new' knowledge.

With the emergence of the new economic geography the interest in the role and nature of agglomeration has increased in the economics literature. It is hypothesized and tested empirically in this literature whether geographic concentration of actors in the system of innovations (e.g., public and private research labs, innovative firms, related industries or business services) affect UII positively (Feldman 1994b, Varga 2000, Koo 2005, Goldstein and Drucker 2006). Though the concept of "regional absorptive capacity" is not used in this literature it is clear that the research question as to the role of agglomeration in the effectiveness of UII implicitly assumes that geographic concentration of the actors of the innovation system increases the capacity of regions to absorb and transfer knowledge to innovation accumulated at local universities. Simulations in Varga (2000) show that the same amounts of university research expenditures result in considerably higher levels of innovation in large concentrations of high technology activities than in smaller metropolitan areas in the US. Thus a positive relationship is found between agglomeration and regional absorptive capacity.

The measurement of regional absorptive capacity is a difficult task and, to the best of our knowledge, few studies have proposed tangible measures. Roper and Love (2006), test how the labour market characteristics of European regions shape regional absorptive capacity. To that end, they add to the usual innovation production function some explanatory variables of interaction effects between the labour market indicators and public and private technology investment. For the authors, these interaction effects capture 'regional absorptive capacity' *effects* rather than 'regional absorptive capacity'

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[3] These authors also mention 'financial capital', but they do not develop its influence.

per se. However, the way they measure the labour market is implicitly a measure of regional absorptive capacity: through what they call structural characteristics (tertiary education and lifelong learning) and individual characteristics (employment in high-tech manufacturing and employment in high-tech services). The results suggest that individual characteristics increase regional absorptive capacity effects more than structural characteristics.

All in all, there is no generally accepted convention as to how regional absorptive capacity can be quantified.

2.3. University-industry interaction can take place inside or outside the region

Regional authorities try to create hybrid organisations to conform a Triple Helix between university, industry and government, even if there are different dynamics among regions. The reason is that sometimes the model of 'best science' is not accepted as the sole basis or distribution of public research funds to regions. Some propose university contribution to regional development as a new source of legitimation (Etzkowitz and Leydesdorff, 2000).

Many regional initiatives to foster UII assume that this interaction will take place within the region. Studies directly investigating the geography of knowledge transfers support this assumption as they report that knowledge from universities tends to spill over locally with a definite distance decay (Jaffe et al., 1993, Audretsch and Feldman 1996, Varga 1998, Acs et al., 2002).

However there is some evidence that geographical proximity in the form of science parks is not likely to promote regional, formal links between university and industry (Vedovello, 1997). Moreover, econometric literature has also found some ground to support that geographic proximity might not always be important. Beise and Stahl (1999) do not find a significant effect of the proportion of scientists employed by universities in municipalities less than 100 kilometres away from the municipality of the firm, on the generation of innovations that could not have been developed without public research by universities. Arundel and Geuna (2004) find that compared to four other information sources, proximity effects are greatest for public research organisations. Schartinger et al. (2002) find a (weakly) significant, negative effect of the average of the spatial distance between the departments of a scientific discipline and firms of an economic sector on the frequency of the recourse to project research. The authors highlight the fact that project research is the only type of interaction in which geographic distance matters (p. 324). Mora-Valentin et al. (2004) do not find a significant effect of the perception of the distance in kilometres and the perception of the time wasted travelling to the partner's address, on the success of the participation in cooperative agreements, both for firms and for public research organisations.

2.4. Regional absorptive capacity and university-industry interaction

The literature review suggests that (i) firms' absorptive capacity increases UII, (ii) the concept of absorptive capacity is applicable to regions, therefore classifiable according to a measure of regional absorptive capacity and (iii) the boundaries of UII are not naturally confined to the region. By combining all these insights, we are in a position to explicitly formulate our hypothesis about a relation between UII and regional absorptive capacity:

Hypothesis. The lower the regional absorptive capacity, the more often university-industry interaction will take place outside the region.

So far, this hypothesis has only been addressed indirectly. For instance, when talking about the localisation of knowledge spillovers, Agrawal (2001) conducts a bibliographic review, according to which such localisation occurs and indirectly implies that the degree of localisation varies across regions. The author finds in the concept of 'regional absorptive capacity' an interesting avenue for future research to explain this variation. Still, the relation is between R&D spillovers –not UII and regional absorptive capacity.

Azagra et al. (2006), through the case study of the Valencian Community in Spain, speculate on the role of absorptive capacity in the context of UII. They find that UII in this region is characterised by some distinctive features: First, faculty members who cooperate with firms in the region will exchange less relevant knowledge than if they resort to firms outside the region. Second, it is easier for faculty members to transfer existing knowledge than to engage in interactive generation of new knowledge. The authors interpret these findings as an idiosyncrasy of a region with low absorptive capacity, in contrast to the importance given to bidirectional flows in UII in more research-intensive contexts (e.g. Meyer-Krahmer and Schmoch, 1998). On the contrary, using a region characterised as of high absorptive capacity, the Basque Country, Castro et al. (2008) find that UII is geographically concentrated.

Applying the same grounds to a nation instead of a region, Vega et al. (2008) find the low absorptive capacity in the productive sector of Bolivia a barrier for strengthening UII. Whereas using another conceptual background, Hussler and Rondé (2007) affirm that epistemic communities are less geographically spread than communities of practice, taking the Alsatian region as a reference. The underlying concern could anyway give place to a hypothesis similar to ours, since we could argue that epistemic communities (communities of practice) are preponderant in regions with higher (lower) absorptive capacity. For instance, the goal of epistemic communities is to produce new knowledge, which is something most likely to occur in a region with high absorptive capacity.

3. Methodology and data

The context of our research is the European Union (EU). We will try to test our hypothesis at the regional level. At the possible expense of eloquence but in the interest of precision, we will use the term intraregional UII to refer to UII within regional borders, and the term interregional UII to refer to UII outside those borders.

The EU R&D Framework Programmes (FP) are a well known source of data for the analysis of cooperation in R&D activities covering a large number of countries. University participation in particular is traceable through this data.

For example, Geuna (1998) shows that the FP are a source of information about university interaction with other partners, although the author does not focus on industry. Using universities as a unit of observation, the econometric estimations suggest that scientific research productivity is determinant for universities to engage at least once in FP projects and then scientific research productivity, together with size and some country and scientific area fixed effects, determine the number of times that universities participate in these projects.

Taking another unit of observation, FP projects themselves, Caloghirou et al. (2001) find that project with at least one firm will be more likely to include at least one university as time goes by, and also the larger the total number of partners is, the longer-term the duration of the project is. They also find some country-coordinator fixed effects, but do not conclude any regional patterns.

Table 1 summarises the samples and methodologies used by these studies and presents the comparison with ours.

Table 1
Comparison of samples and methodologies between other works and ours

Work	Geuna (1998)	Caloghirou et al. (2001)	Present study
FPs	1-3	1-4	6
Time period		1983-1996	
Dependent variable(s)	1) Probability that a university participates in a project (1,0) 2) Number of participations of a university in FP projects	Probability that a project includes at least one university (1,0)	Counts and money
Type of cooperation	University-others	University-industry	University-industry
Techniques	1) Tobit 2) Sample selection (Probit + Truncated)	Probit	Tobit with panel data
Unit of observation	University	Project	Region-year
Type of sample	Cross-section	Cross-section	Panel

In order to test our hypothesis, we obtained in September 2007 a unique database of participations to the 6th EU R&D Framework Programme (FP6). This is a 'live' database constructed internally by the Commission, recording 8,861 distinct projects and 69,260 participations involving universities, private firms, public or private research centres and other organisations. In contrast to other studies, ours analysis here is not confined to the number of participations but also includes information on the amount of funding per participant.

Given our focus on UII, we narrowed down the database to a subset of projects with at least one university and one firm. Additionally, in line with the primary focus of the FP, we confined our analysis to the EU27 members.

To assess the extent of interregionalisation, we identified whether universities and firms belonged to the same region by attributing to each project the region of the university (duplicating projects in the case of universities from more than one region[4]), and checking whether firms participating in the same project were from the same region as the university. If the firm was from a region other than that of the university then the participation was designated 'interregional'; otherwise it was designated 'intraregional' (a participation with joint university-industry participation where both the university and

[4] For projects with more than one university, we duplicated observations, attributing a distinct nationality in each duplicate project. We then added as many duplicate project observations as the discrete nationalities of participating universities.

the company were from the same regions).

We therefore constructed the following variables:

- ❖ INTERREG_C: number of interregional UII projects in the FP6
- ❖ INTERREG_M: value of interregional UII projects in the FP6

We take logs for the econometric estimations, calling the variables lnINTERREG_C and lnINTERREG_M, respectively.

These variables express absolute measures of interregional UII. In seeking an indicator of relative measures, we opt for the share of interregionalisation of UII, that is the ratio of interregional to all UII projects. We define thus the next variables:

- ❖ sINTERREG_C: number of interregional UII projects over total number of UII projects in the FP6
- ❖ sINTERREG_M: value of interregional UII projects over total value of UII projects in the FP6

As our database contains information on the number and value of intraregional UII, we repeated the above procedure creating similar variables as for interregional UII:

- ❖ INTRAREG_C: number of intraregional UII projects in the FP6 (lnINTRAREG_C if in logs)
- ❖ INTRAREG_M: value of intraregional UII projects in the FP6 (lnINTRAREG_M if in logs)
- ❖ sINTRAREG_C: number of intraregional UII projects over total number of UII projects in the FP6
- ❖ sINTRAREG_M: value of intraregional UII projects over total value of UII projects in the FP6

An example may clarify the interpretation of the variables. If we focus on a single project, the one in Table 2 has 6 universities and 2 firms, i.e. 12 UIIs. The project has other types of institutions but we do not count them. The regions of the six universities are DE71, ES51, FR43, ITC1, ITG2 and UKH2, which we include in the panel, i.e. the unit of observation is the region of the university. The regions of the firms are ES51 and PT16. Since there was a university from ES51, one out of the twelve UIIs has been intraregional (INTRAREG_C=1). The remaining 11 UIIs have been interregional (INTERREG_C=11). Therefore, sINTERREG_C=0.92.

Table 2
An example of the construction of the dependent variables

Region of university	INTRAREG_C (number of interactions with firms of the same region) (a)	INTERREG_C (number of interactions with firms from other regions) (b)	Total number of interactions (c=a+b)	sINTERREG_C (b/c)
DE71	0	2	2	1
ES51	1	1	2	0.5
FR43	0	2	2	1
ITC1	0	2	2	1
ITG2	0	2	2	1
UKH2	0	2	2	1
Total	1	11	12	0.92

Given the non-standard regional coding used in the database (a mixture of NUTS1, NUTS2 and NUTS3 codes in addition to outdated national classifications)[5], this exercise required considerable harmonisation, much of which had to be done manually. In due course, we were also able to improve the completeness of the regional identifier using information from the participant's address field.

In order to perform the econometric analysis we specify the following function:

$$\text{INTERREG\_C}^{*}_{i,t} = \alpha + \beta_1 \text{BERD}_{i,t-1} + \beta_2 \text{HERD}_{i,t-1} + \beta_3 \text{LEAD}_{i,t} + \beta_4 \text{GDP}_{i,t-1} + u_{i,t} \quad (1)$$

Where INTERREG_C* is an unobserved random variable related to the original INTERREG_C through the following transformation:

$$\begin{aligned} &\text{INTERREG\_C}_{i,t} = 0 \text{ if } \text{INTERREG\_C}^{*}_{i,t} \leq 0, \\ &\text{INTERREG\_C}_{i,t} = \text{INTERREG\_C}^{*}_{i,t} \text{ if } \text{INTERREG\_C}^{*}_{i,t} > 0 \end{aligned} \quad (2)$$

We opt for a logarithmic functional form[6] for the usual reasons (i.e. scaling variables expressed in different units of measurement, allowing the interpretation of coefficients as elasticities, suitability to non-linear relationships and lessening of the influence of outliers), so the actual function to be estimated is:

$$\text{lnINTERREG\_C}^{*}_{i,t} = \alpha + \beta_1 \text{lnBERD}_{i,t-1} + \beta_2 \text{lnHERD}_{i,t-1} + \beta_3 \text{LEAD}_{i,t} + \beta_4 \text{lnGDP}_{i,t-1} + u_{i,t} \quad (3)$$

We ran analogous regressions for lnINTERREG_M, sINTERREG_c and sINTERREG_c. So for each region *i* at year *t*, the degree of interregionalisation is a function of the following independent variables:

- (ln)BERD: (natural log of) business expenditure on R&D (BERD). This is a proxy for absorptive capacity. If our hypothesis were true, a negative sign would be expected for lnBERD
- (ln)HERD: (natural log of) higher education expenditure on R&D (HERD). It is a control for the strength of universities in the region. A positive significant parameter estimate would provide stronger support to the hypothesis since it would suggest that excellent universities interact with firms outside the region.
- LEAD[7]: count of number of times university(-ies) in the region appear as coordinators in FP projects. A similar control to lnHERD, it identifies when universities act as lead partners. The rationale to include it is to identify relationships that are actively built by a university. We must take into account that in most of the cases there are "core participants" of any FP project with some academic institutions who have major influence on the selection of the particular set of partners including industrial partners. It might be possible that a leading university (part of the core of an FP) selects an industrial partner from its region. Without this variable, the results from the regression could be misleading. Our

[5] For some countries there was a mismatch between the NUTS code reported in the database and contemporary NUTS classifications used for the same regions by Eurostat. This is probably due to comprehensive national coding revisions (as e.g. in the case of Bulgaria, Denmark, Romania, Sweden and Slovenia) and to smaller ad hoc changes (as e.g. in the German regions DEE2, DEE3 which have been merged into DEE0).

[6] The transformation introduces a complication, as the logarithm of zero is undefined. A common solution is to add a small positive number to all observations before taking logarithms. We added 0.0001, so that when INTERREG_C or INTERREG_M are equal to 0, lnINTERREG_C and lnINTERREG_M are equal to -9.21.

[7] As this variable takes mostly low values (min=0, max=13, mean=0.55), we retain it in its original form.

measure is the count of number of times university(-ies) in the region appear as coordinators in FP projects, coming from the FP6 database.

- (ln)GDP: (natural log of) GDP in millions of euro. It is a control for the wealth of the region.

We repeated the former regressions for the intraregional variables, where the expected sign of the coefficients should be the opposite of those just explained.

We obtained BERD, HERD and GDP from the Eurostat online public database, which we then matched to the FP6 panel. We lagged them by one period in order to limit potential endogeneity.

Using this method, we constructed a panel of five years (2003-2007) for the EU's 27 member states, yielding around 800 observations after having dropped missing values (mainly of BERD and HERD).[8]

The dependent variables are censored. The absolute measures INTERREG_C and INTERREG_M have a lower limit of 0 because an observation equal to zero may be the outcome of two different distributions: for all regions, the discrete choice of not participating in UII FP projects; for regions that chose to participate, the decision on the degree of participation in interregional projects. In addition, the relative measures sINTER_C and sINTER_M have an upper limit of 1 because an observation equal to one may be the outcome of two different distributions: for all regions, the discrete choice of participating in UII FP projects, interregional by default; for regions that chose to participate, the decision on the degree of participation in interregional projects. The same logic applies to the intraregional variables. Therefore, since all the dependent variables are censored, the Tobit model appears to be adequate for the econometric estimations.

The panel structure of our data raises an additional issue, namely the choice between a random effects and fixed effects estimator. In that respect, the need for a tobit model, constrains us to random effects, as the alternatives are not very appealing[9]. A random effects estimator is certainly attractive given our research question (our interest in explaining cross sectional variation) and the structure of our panel (limited time-series variation). Random effects procedures are appropriate where the sample can be safely assumed to be a random draw from the population and the within-panel error term uncorrelated with the explanatory variables (Dougherty, 2007: 419). In our case, we have no particular reason to expect that our sample is not random, but we are unable to evaluate the validity of the second assumption. This constraint need not be detrimental though, provided one keeps an open mind about the possibility of omitted variable bias while drawing inferences.

4. Descriptive results

As our sample draws data from FP, research networks are, almost by design, international. While this international bias skews our sample, in that we are likely to witness more interregional UIIs than we would if observing 'natural' collaborations, it

[8] Our near-complete sample of UII across EU regions is somewhat marred by missing year-region observations for HERD, BERD and GDP. To counter this issue we have followed the common convention of filling missing year-region observations with the average value of the preceding and following years. This made possible the recuperation of a small number of observations for BERD (150) and HERD (49), but not for GDP that had no missing values meeting the above criterion.

[9] Conditional fixed effects model are not common practice as there does not exist a sufficient statistic allowing the fixed effects to be conditioned out of the likelihood. Unconditional fixed effects with dummy variables for the members of the cross-section produce biased estimates (from http://www.stata.com/help.cgi?xttobit, last access: 19/01/2010.)

also carries a strength of particular importance to our study: the remaining few intraregional UIIs are likely to represent important, high value ties (perhaps even indispensable), rather than casual collaboration patterns.

Table 3 presents some descriptive statistics. Overall about two-thirds (70%) of the 1370 regions in our sample had interregional UII, with the average EU region being home to about 32 such contracts worth about 9 million Euros. Intraregional UII was much less common, occurring in just under one third (30%)[10] of regions, with the average EU region barely having one such contract, worth on average about 300,000 Euros.

Table 3
Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
INTERREG_C	1370	32.97226	54.12484	0	431
INTERREG_M	1370	9021323	1.69e+07	0	1.51e+08
sINTERREG_C	1370	.6850222	.4482659	0	1
sINTERREG_M	1370	.6834998	.4507568	0	1
INTRAREG_C	1370	1.143796	3.21527	0	46
INTRAREG_M	1370	321760.2	1213793	0	2.17e+07
sINTRAREG_C	1370	.0171676	.043624	0	.6666667
sINTRAREG_M	1370	.0157703	.0472103	0	.5681713
BERD	1020	401.772	761.2857	0	8943.631
HERD	873	150.6046	207.75	0	2065.085
LEAD	1370	.549635	1.285738	0	13
GDP	1345	37941.2	42575.04	809.1	442538.4

Figure 1 and Figure 2 present two maps of intraregional UII across EU27 regions –one for aggregate budgets (INTRAREG_M) and one for intraregional budget shares (sINTRAREG_M). Darker areas (denoting higher values) seem to largely coincide with highly industrialised regions (much of northern Italy, Catalonia and the Basque Country (ES), Rhône Alpes (FR), Hamburg (DE) etc.) and include the greater regions of major EU capitals. On the surface, this pattern appears to be in agreement with our hypothesis: in such centres, one would expect not only high business R&D expenditures, but also a history of cooperation and an associated familiarity (through personal contacts and local networks) that could permit intraregional UII. Table 4, a list of the top 25 EU regions with intraregional UIIs, reinforces this impression. There are also notable exceptions to the above pattern, including Andalucía (ES), Midi-Pyrénées (FR), Sud-Est (RO), Sicily (IT) and Severoiztochen (BG); regions that are not commonly associated with high-technology industry. While it is true that some of these regions are improving their industrial R&D capacities (as partly reflected in the recent regional innovation scoreboard (Hollanders et al., 2009)) and/or receiving considerable policy attention and funding as cohesion ('Objective 1') regions[11], it is highly likely that we are witnessing

[10] As any given region can have both intraregional and interregional projects (i.e. the two categories are not mutually exclusive), the fact that the percentages of the two variables discussed here add up to a hundred is coincidental.

[11] Highly specialised clusters of localised collaboration may also account for this observation. For instance, the Etna Valley technological district in Sicily (specialising in telecommunications and electronics), is supported by European and national funds and offers the possibility of research student placements in companies (Distretti Industriali Italiani, 2009), conditions that may conceivably favour

here the effects of a region's size, as larger regions can accommodate a larger number of companies and hence increase the likelihood of intraregional UII.

intraregional UII.

Figure 1
Intraregional UII across EU27 NUTS2 regions (INTRAREG_M: aggregate budgets of FP projects)

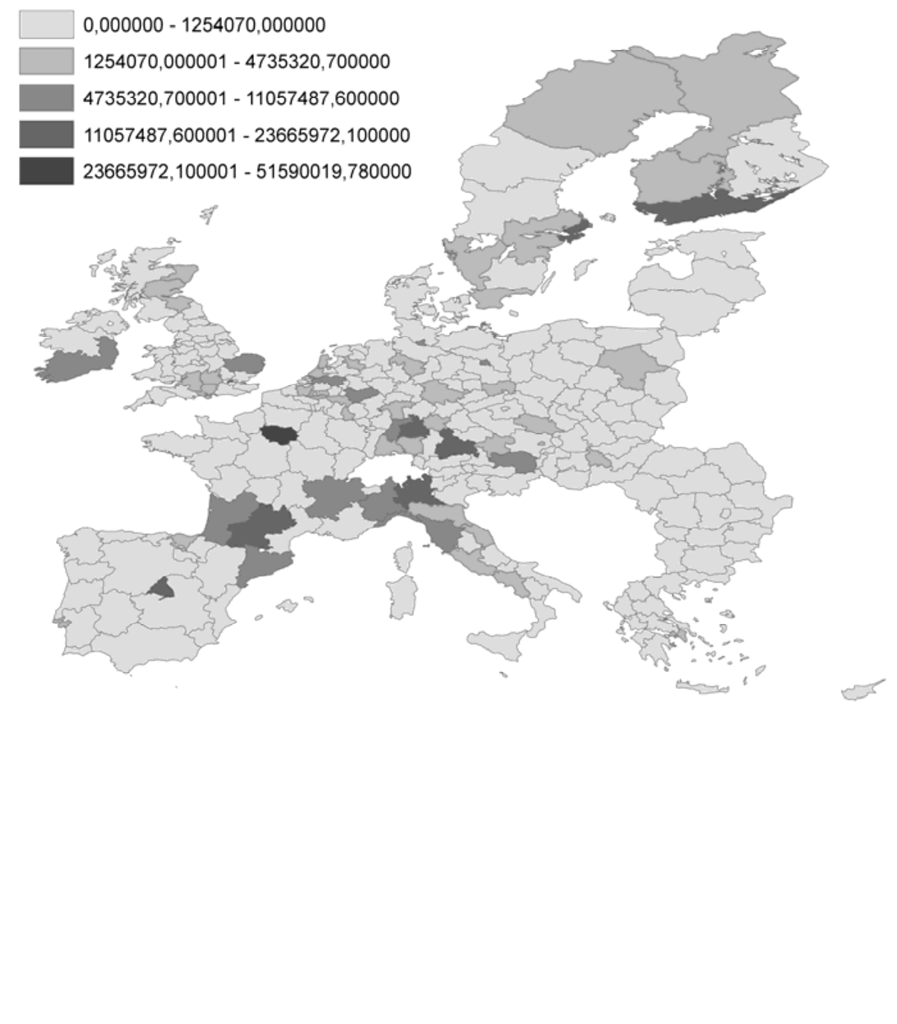

Figure 2
Intraregional UII across EU27 NUTS2 regions (sINTRAREG_M: shares of FP budgets)

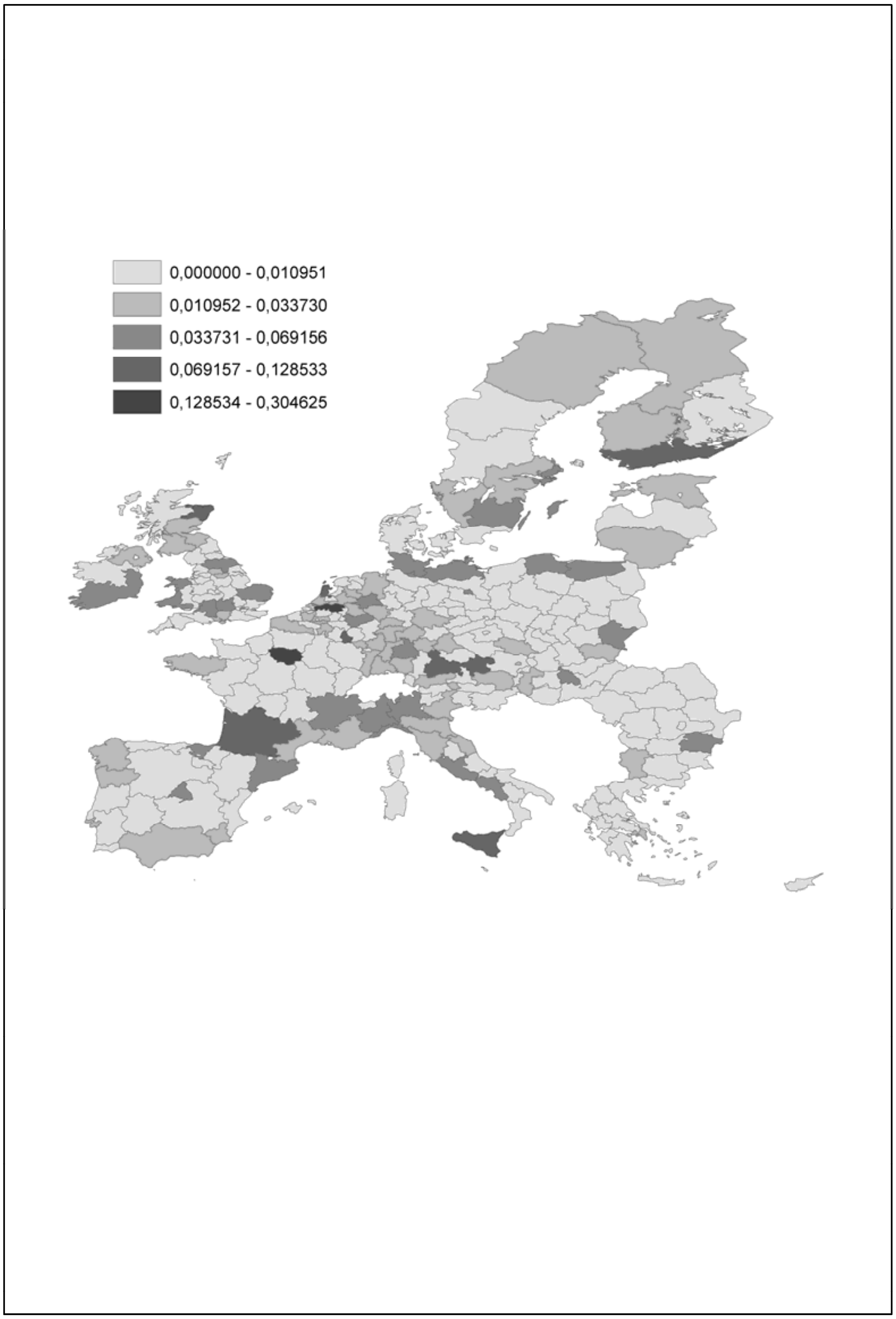

Table 4
Top 25 Regions with intraregional UII

Region name	NUTS Code	Intraregional UIIs (INTRAREG_C)
Île de France	FR10	145
Lombardia	ITC4	62
Stockholm	SE11	62
Inner London	UKI1	50
Cataluña	ES51	49
Oberbayern	DE21	46
Comunidad de Madrid	ES30	46
Stuttgart	DE11	43
Etelä-Suomi	FI18	42
Köln	DEA2	36
Attiki	GR30	35
Toscana	ITE1	33
Southern and Eastern	IE02	32
Rhône-Alpes	FR71	29
Kozep-Magyarorszag	HU10	29
Emilia-Romagna	ITD5	24
Zuid-Holland	NL33	24
East Anglia	UKH1	24
Piemonte	ITC1	22
Wien	AT13	20
Midi-Pyrénées	FR62	20
Prov. Vlaams-Brabant	BE24	19
Karlsruhe	DE12	18
Berlin	DE30	18
Lisboa	PT17	18

Table 5 presents how INTRAREG varies across EU regions according to their BERD. For ease of presentation, we have divided BERD into quartiles. Just above one-third of all regions has had intraregional UII in FP6. We can observe that a greater proportion of UII remains contained within the regions as we move to upper BERD quartiles. This is in agreement with our hypothesis, but will have to be confirmed in a multivariate context.

Table 5
Intraregionalisation of university-industry interaction in the 6th FP: Quartiles of BERD (counts and budgets)

Variable (values)	Lower quartile (€0m- €32.129m)	Mid-lower quartile (€32.322m- €131.587m)	Mid-upper quartile (€132.212m- €422.306m)	Upper quartile (€425.36m- €8943.631m)	Total
INTRAREG_C					
(=0)	204	161	124	82	571
(=1)	10	31	36	28	105
(>1)	4	25	58	107	194
Total	218	217	218	217	870
INTRAREG_M					
(=0)	205	162	124	83	574
(=1)	9	25	17	8	59
(>1)	4	30	77	126	237
Total	218	217	218	217	870

5. Econometric results

5.1. Aggregate UII

We carry on to the econometric analysis with Tobit models. Regression estimates are presented in Table 6.[12]

The signs of the coefficients are correct according to our expectations. All four models provide evidence of a negative relation between our proxy for absorptive capacity, lnBERD, and the degree of interregionalisation, so we confirm the central hypothesis of the paper. Increasing regional firms' R&D will decrease UII beyond regional borders.

Our control variable for university R&D reinforces this story. Higher volumes of HERD have a significant, positive, association with the degree of interregionalisation. Hence, increasing HERD will augment UII outside regional borders. Notice that the coefficients of HERD are always higher in absolute values than those of BERD are, so the net impact of an equal percentage increase of HERD and BERD will most likely reduce interregionalisation of UII. In other words, BERD needs to increase faster than HERD to compensate for the interregionalisation of UII.

Wealth or its proxy GDP correlates positively and significantly to interregionalisation in absolute but not in relative terms, which confirms the importance of controlling for size.

[12] We acknowledge here the convenience offered by the table-producing tool developed by Wada (2009).

Table 6
Tobit models of the determinants of interregionalisation of UII in the FP6

	1 lnINTERREG_C	2 lnINTERREG_M	3 sINTERREG_C	4 sINTERREG_M
lnBERD	-0.360**	-0.709*	-0.0622**	-0.0645**
	(0.181)	(0.368)	(0.0285)	(0.0290)
lnHERD	1.829***	3.625***	0.214***	0.217***
	(0.212)	(0.430)	(0.0328)	(0.0334)
LEAD	0.307**	0.416	-0.0482**	-0.0468**
	(0.139)	(0.289)	(0.0223)	(0.0227)
lnGDP	1.515***	2.772***	0.0884	0.0924
	(0.457)	(0.928)	(0.0696)	(0.0707)
Constant	-21.36***	-30.98***	-0.531	-0.578
	(3.892)	(7.904)	(0.590)	(0.599)
Observations	802	802	802	802
Number of regions	234	234	234	234
Log likelihood	-2064.7163	-2521.2767	-745.76741	-751.14699
Prob > χ^2	0.000	0.000	0.000	0.000

Standard errors in parentheses. *, ** and *** denote statistical significance at the 0.1, 0.05 and 0.01 levels respectively

The fact that universities assume the leadership of UII in FP projects has an ambiguous influence. It increases the number of participations in such projects, but not their value, and decreases the share of participations in such projects. Let us be cautious and leave the interpretation until we explore the intraregional variables. We do it in Table 7.

Table 7
Tobit models of the determinants of intraregionalisation of UII in the FP6

	1 lnINTRAREG_C	2 lnINTRAREG_M	3 sINTRAREG_C	4 sINTRAREG_M
lnBERD	0.288	0.829	0.00461	0.00644*
	(0.343)	(0.737)	(0.00388)	(0.00363)
lnHERD	2.480***	5.902***	0.0132***	0.0148***
	(0.467)	(1.039)	(0.00485)	(0.00464)
LEAD	1.054***	2.159***	0.00795***	0.00599***
	(0.226)	(0.494)	(0.00267)	(0.00229)
lnGDP	2.905***	5.592***	0.0297***	0.0272***
	(0.759)	(1.617)	(0.00861)	(0.00798)
Constant	-52.86***	-100.3***	-0.431***	-0.418***
	(6.600)	(14.06)	(0.0752)	(0.0692)
Observations	802	802	802	802
Number of regions	234	234	234	234
Log likelihood	-1256.8391	-1486.8986	109.67402	176.93954
Prob > χ^2	0.000	0.000	0.000	0.000

Standard errors in parentheses. *, ** and *** denote statistical significance at the 0.1, 0.05 and 0.01 levels respectively

The impact of lnBERD on intraregional participation in UII FP projects is not significant in the first three columns. However, it is positive and significant in the fourth column (variable sINTRAREG_M), which is consistent with our central hypothesis: increasing BERD makes firms interact less intensely with universities outside the region and the same or more intensely with universities within the region.

University R&D has a positive impact on intraregional UII, as it had on interregional UII. Hence, it has the dual role of making it compatible interaction with firms inside and outside the region. However, it is possible to notice that the coefficients of lnHERD in Table 6 are much higher than in Table 7 for the relative measures (columns 3-4). Concretely, the impact of lnHERD is around 15 times higher on the share of interregionalisation than on the share of intraregionalisation. Taken at face value, an increase in university R&D will augment university interaction with firms outside the region faster than with firms within the region. However, the imposition of a random effects model and the possible noise in the data advocate caution, so a more tentative interpretation is that the dual role of university R&D appears to be asymmetric and in favour of interregional UII.[13]

Regional leadership of UII FP projects has a clear significant, positive impact on intraregional UII. Moreover, the coefficients of LEAD are higher in Table 7 than in Table 6 for the absolute measures (variables in logs), and are positive in Table 7 while they are negative in Table 6 for the relative measures (variables in shares). This result suggests that the presence of leading universities in the regions is a compensating mechanism for interaction to remain in the region.

The coefficients of lnGDP are positive and significant for absolute intraregionalisation (columns 1-2), as they were in the case of absolute interregionalisation. In addition, they are positive and significant for relative intraregionalisation (columns 3-4), despite not being significant for relative interregionalisation. We may interpret that while GDP controls for size, it captures parts of absorptive capacity that are not included in BERD and which are influential for the share of intraregional UII, not for the share of interregional UII.

5.2. A test for robustness with a more homogeneous measure of UII

The measures of counts and value used so far combine a heterogeneous mixture of activities. FP6 classifies its activities into (i) specific programmes, that are subdivided into (ii) thematic areas and/or (iii) instruments. Thematic areas and instruments overlap in most instances. EC (2002) provides a quick guide to these differences, and we will give some hints in what follows.

Breaking down the data is convenient for technical and substantive reasons. Technically, the construction of a more homogenous and meaningful measure of UII, should reduce the amount of noise contained in the dependent variables[14]. From a substantive perspective, reaching the level of thematic areas is especially interesting

[13] Certainly, the coefficients of the absolute measures in Table 6 are smaller than in Table 7 (columns 1-2). One may wonder how it is possible that variables in relative measures behave differently than in absolute measures. One reason is that the ratio of the coefficients in Table 7 over those in Table 6 is equal to 1, so the difference is not remarkable. More technical reasons are that: a) the Tobit estimation is not linear; b) the absolute measures are nevertheless taken in logs, which introduce additional non-linearity; c) one has to take into account the effect of the rest of the parameters in the model. Hence, it is compatible that variables in shares behave differently from absolute variables.

[14] This may not happen necessarily, as the exclusion of a large number of projects means that point estimates are produced from an overall lower number of observations – potentially introducing further 'noise'.

because they broadly correspond to scientific disciplines.

In order to get to the level of thematic areas, for the sake of clarity, we start by breaking the data down by specific programme. There are three (Table 8): (i) “Integrating and strengthening the ERA”, the bulk of the FP6 (92% of UIIs), and mostly concerned with research projects; (ii) “Structuring the ERA”, less numerous and more concerned with mobility of human resources and development of infrastructures (6%); (iii) Euratom, a small proportion of UIIs on nuclear research (2%).

The first one, “Integrating and strengthening the ERA”, is the most relevant for this study, because it is the largest and contains the thematic areas that can be attached to scientific disciplines. These are numbered from 1 to 7 (that is to say, numbered in the original dataset), while other thematic areas, not numbered, cannot be attached to scientific disciplines).

Out of the seven numbered thematic areas, 1-6 are closer to natural sciences, whether 7 is closer to social sciences. This is arguable, but not vital for our analysis. Areas 1-7 also encompass a narrower variety of instruments, which make it a more homogeneous subset. For the sake of building a less noisy variable, we will test whether our hypothesis holds true for an aggregate of the grey-shaded quadrant in Table 8.

Table 8
Number of UIIs in the FP6 by specific programme, thematic priority and instrument

	NoE	IP	STREP	CA	SSA	CRAFT	CLR	I3	II	MCA	Total
Integrating and strengthening the ERA	54427	99780	35877	13101	2832	3525	1713				211255
1. Life sciences, genomics and biotechnology for health	10722	15545	5279	1336	321						33203
2. Information society technologies	34852	26697	10148	2607	972						75276
3. Nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices	2146	11922	5774	2996	164						23002
4. Aeronautics and space	154	7560	5564	312	93						13683
5. Food quality and safety	1402	10886	1829	1367	540						16024
6. Sustainable development, global change and ecosystems	5151	26933	4821	2773	208						39886
7. Citizens and governance in a knowledge-based society		105	24	187							316
Horizontal research activities involving SMEs						3525	1713				5238
Policy support and anticipating scientific and technological needs			2246	1206	376						3828
Specific measures in support of international cooperation		132	192	298	158						780
Support for the coordination of activities				19							19
Structuring the ERA		96	170	462	1407	88		2721	2215	5855	13014
Human resources and mobility					12					5855	5867
Research and innovation				300	236	88					624
Research infrastructures		96	20	126	1071			2721	2215		6249
Science and society			150	36	88						274
Euratom	510	2573	377	1257	42						4759
Total	54937	102449	36424	14820	4281	3613	1713	2721	2215	5855	229028

NoE: Networks of Excellence; IP: Integrated Projects; STREP: Specific Targeted Research Projects; CA: Coordination Actions; SSA: Specific Support Actions; CRAFT: Co-operative research projects; CLR: Collective research projects; I3: Integrated Infrastructure Initiatives; II: Specific actions to promote research infrastructures –other than I3; MCA: Marie Curie Actions

The regression results (Table 9) are identical to those for the model with the aggregated data (Table 6) regarding the impact of BERD on the relative measures of interregionalisation (columns 3-4). However, such impact becomes statistically non-significant on the absolute measures of interregionalisation (columns 1-2). One could say that support to the central hypothesis is not as strong as before.

Table 9
Tobit models of the determinants of interregionalisation of UII in the FP6, in the specific programme "Integrating and strengthening the ERA" and the six thematic priorities corresponding to natural sciences

	1 lnINTERREG_C	2 lnINTERREG_M	3 sINTERREG_C	4 sINTERREG_M
lnBERD	-0.240	-0.513	-0.0638*	-0.0645**
	(0.197)	(0.400)	(0.0328)	(0.0290)
lnHERD	1.901***	3.829***	0.251***	0.217***
	(0.232)	(0.470)	(0.0383)	(0.0334)
LEAD	0.352**	0.510*	-0.0520**	-0.0468**
	(0.148)	(0.307)	(0.0255)	(0.0227)
lnGDP	1.453***	2.674***	0.112	0.0924
	(0.499)	(1.012)	(0.0801)	(0.0707)
Constant	-22.17***	-32.75***	-0.922	-0.578
	(4.246)	(8.620)	(0.680)	(0.599)
Observations	802	802	802	802
Number of regions	234	234	234	234
Log likelihood	-2044.4334	-2487.5882	-754.85625	-751.14699
Prob > χ^2	0.000	0.000	0.000	0.000

Standard errors in parentheses. *, ** and *** denote statistical significance at the 0.1, 0.05 and 0.01 levels respectively

The results reported in Table 10, however are somewhat closer to our expectations. The positive impact of lnBERD on intraregionalisation is more significant than it was in Table 7, favouring our hypothesis. Overall, when using the more homogeneous dependent variables statistical significance shifts from the interregional models to the intraregional models, but the conclusions are the same.

For the rest of coefficients, the findings are the same as with the aggregate measure of FP projects. Differences in the substitution effect between BERD and HERD on interregionalisation are exacerbated. So are differences in the complementary effect of HERD on interregionalisation and intraregionalisation, in favour of the first one. The compensating effect of LEAD remains the same.

Table 10
Tobit models of the determinants of intraregionalisation of UII in the FP6, in the specific programme "Integrating and strengthening the ERA" and the six thematic priorities corresponding to natural sciences

	1 lnINTRAREG_C	2 lnINTRAREG_M	3 sINTRAREG_C	4 sINTRAREG_M
lnBERD	0.772**	1.917**	0.00987**	0.0118***
	(0.377)	(0.827)	(0.00436)	(0.00413)
lnHERD	2.243***	5.420***	0.0110**	0.0129**
	(0.502)	(1.136)	(0.00530)	(0.00511)
LEAD	1.228***	2.590***	0.00945***	0.00721***
	(0.246)	(0.544)	(0.00296)	(0.00259)
lnGDP	2.678***	5.190***	0.0289***	0.0270***
	(0.804)	(1.745)	(0.00935)	(0.00873)
Constant	-53.76***	-103.7***	-0.458***	-0.452***
	(7.050)	(15.29)	(0.0823)	(0.0763)
Observations	802	802	802	802
Number of regions	234	234	234	234
Log likelihood	-1136.7128	-1337.4977	48.888861	101.14096
Prob > χ^2	0.000	0.000	0.000	0.000

Standard errors in parentheses. *, ** and *** denote statistical significance at the 0.1, 0.05 and 0.01 levels respectively

6. Conclusions

The results so far point to the importance of regional absorptive capacity for explaining why UII is more delocalised in some EU regions than in others. For a given level of excellence of universities in the region, stronger scientific firms will tend to interact with them. Hence, regional policy makers may find that promoting firms' R&D in their region will not only boost local innovation directly but also through increased interaction with local universities.

On the contrary, promoting excellence will lead universities outside the region more than inside the region, for a given level of local firms' absorptive capacity. This means that universities establish cross-border links that may complement firms' preference for localisation. However, and without making a plea for techno-regionalism, it also implies that policymakers should be aware that the objective of maximising UII is not necessarily compatible with the objective of maximising university contribution to local development.

This interpretation of the findings would have some policy implications. It would imply that policy makers could refine their objectives regarding UII by defining to what extent it should be localised. For established instruments such as the FP, the interregionalisation of UII will not be successful if some regions perceive that it will lead to excessive delocalisation of UII, so compensating measures may be needed. Increasing the participation of universities as lead partners in projects with firms could be a possible measure.

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