ACCESS TO UNIVERSITIES' PUBLIC KNOWLEDGE: WHO'S MORE REGIONALIST?

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Abstract
Patent citations are widely used indicators of knowledge flows. One originality of this paper is to track not patent-to-patent or paper-to-patent citations as usual but university-to-firms' patent citations. Another one is not to explain citations as a function of distance between cited and cited regions but to explain regional and non-regional citations as a function of the characteristics of knowledge supply and demand in the region –a complementary approach to the geography of knowledge flows. Using a dataset of European Union regions in years 1997-2007, we find that fostering university R&D capacity enlarges the attractiveness of the local university knowledge base for firms in the region. However, it has a trade-off, since firms will take less resource to university knowledge produced elsewhere. It is possible to compensate this through increases in local business absorptive capacity, which will enable firms to access university knowledge outside the region.

Conference Topic
Technology and Innovation Including Patent Analysis (Topic 6) and Science Policy and Research Evaluation: Quantitative and Qualitative Approaches (Topic 3).

Introduction

Codified university knowledge such as patenting and scientific publications may have an influence on innovation in regions because of the flow of technological knowledge between universities and firms. This flow of knowledge can take place through a variety of interaction channels between academics and firms (by reading the patent and/or a scientific paper, or via direct conversation or informal meetings with the academic inventor or researcher, through the hiring of graduate or doctorate students, etc.). However, sometimes there is a mismatch between the university-codified knowledge produced in the region and the firms' acquisition of that knowledge. This paper explores the causes explaining why firms use the inward regional university knowledge and why they acquire that knowledge elsewhere outside the region.

Our interest for this topic is motivated for several facts. First, the regional focus for analyzing the acquisition of knowledge from universities is suitable given the growing role of policies at regional level to achieve the European Research Area (ERA). The program to develop the ERA is primarily a partnership between the European Commission and the member states; but the Commission, the Council and the Committee of the Regions all see a role for the regions in the ERA, as a result of a greater involvement of the regions in research and innovation policies (Charles et al., 2009). Second, some regions generate scientific and technological knowledge in their universities, but sometimes regions producing that codified knowledge are unable to fully absorb it or exploit it (Caragliu and Nijkamp, 2012). Third, despite the importance of knowing what explains the acquisition of university knowledge outside or inside the region for regional policy, only a few recent papers have analyzed this topic. For example, Acosta et al. (2011b), study the outside dimension of research collaboration patterns; Abramo et al. (2010) addresses both dimensions for a single country; and Azagra (2012) takes a large number of countries and years to analyze the national patterns of accessing public knowledge. None of this previous research centers on a regional perspective for EU27.

Particularly, two groups of hypotheses are tested about the role of absorptive capacity for academic knowledge, and the importance of the regional presence of regional scientific and technological opportunities on the firms' acquisition of university knowledge. For this purpose we draw on a regional sample of around 6,000 university references (both patents and papers) contained in 4,000 firms' patents across EU27 regions for 1997-2007. The econometric results show a significant role of the university opportunities to increase the acquisition of inward university knowledge, while the firm absorptive capacity is not relevant in explaining the use of knowledge by the firms located in the same region where the knowledge is produced. However, the outward acquisition of knowledge is positively explained for the absorptive capacity and negatively for the regional opportunities for spillovers.

The paper is organized as follows. Section 2 reviews the relevant literature and establishes the hypotheses. Section 3 discusses the empirical framework. Section 4 explains the data and provides summary statistics. Section IV presents the empirical results. We briefly summarize the conclusions, policy implications, and discuss future research in the final Section.

Literature review and hypotheses

This paper has a regional focus, but the proposal of hypotheses describing the causes of the regional acquisition of university knowledge requires a discussion at firm level. In this respect, this review starts by including some ideas about the open innovation paradigm that helps to classify the process of acquisition of university knowledge and to explain why firms engage in acquiring external knowledge. Afterwards this literature is linked with the empirical background on the geographical dimension of knowledge sourcing, which discusses the role of proximity in the process of absorbing knowledge. Finally, we take into account the supply side perspective by referring to some papers stressing the relevance of the availability and characteristics of university knowledge for the process of acquisition of knowledge by firms to take place.

The process of incorporating new knowledge into firms from other institutions such as universities has been recently discussed in the frame of the open innovation paradigm. According to the open innovation model, firms incorporate external as well as internal ideas, and internal and external paths to market, as they look to advance their technology (Chesbrough, 2003, 2006). Since Chesbrough's seminal work, a considerable number of papers have analysed the open innovation process at various levels, including at firm, industry and region levels (see van de Vrande et al., 2009 for a review), and new trends and directions have been identified (see, for example, Gassmann et al., 2010). This literature provides an analytical framework to explain the process of acquisition of knowledge by firms.

The open innovation ideas assume acquiring knowledge from different sources. Dahlander and Gann (2010) developed an analytical framework by structuring the process of open innovation in two dimensions: inbound/outbound (see also Chesbrough, 2006, Gassmann and Enkel, 2004) and pecuniary/non-pecuniary. Inbound open innovation is an outside-inwards process and involves opening the innovation process to knowledge exploration. External knowledge exploration refers to the acquisition of knowledge from external sources. By contrast, outbound open innovation is an inside-outwards process and includes opening the innovation process to knowledge exploitation. Open innovation is then a broad concept encompassing different dimensions and it is useful to classify the type of acquisition of knowledge addressed in this paper. According to this literature, the firms' acquisition of knowledge from university outputs such as patents open to public and scientific papers is a kind of inbound and non-pecuniary process of innovation. From a spatial perspective, regions exhibit similar patterns to firms; innovative success might depend on the appropriate combination of knowledge inputs from local and regional as well as national and global sources of knowledge (Kratke, 2010); moreover as pointed by Cooke et al., (2000) and Cooke (2005), it is impossible to discuss innovation processes and policies without reference to the interactions of local–regional, national and global actors and institutions.

The empirical evidence on businesses' external knowledge sourcing through university spillovers has revealed two facts: First, there is a geographical dimension in the external process of knowledge acquisition from universities. The relevant role of distance has been tested largely by a long list of empirical papers on university spillovers (e.g. Anselin et al. 1997, 2000; Feldman and Florida 1994; Fischer and Varga 2003; Jaffe 1989; Varga 1998). The main finding of these studies is that knowledge spillovers from universities are localized and contribute to higher rates of corporate patents or innovations in geographically bound areas. Moreover, knowledge spillovers are usually "confined largely to the region in which the research takes place" (Hewitt-Dundas, 2011). Second, spillovers from neighbouring sources of knowledge inside the region or other ways of acquisition of knowledge outside the region do not occur automatically. A certain degree of "absorptive capacity" (Cohen and Levinthal, 1990) is necessary; that is, firms must have the ability to recognise the value of new, external information, assimilate it, and apply it" (Cohen and Levinthal, 1990). This means that factors hampering the open innovation process such as culture, modes of organization, bureaucratic elements, lack of resources, etc. (van de Vrande et al. 2009) would be encompassed in the broad concept of absorptive capacity. Using the terminology of the open innovation paradigm, absorptive capacity is "a pre-condition for organising inbound open innovation activities" (Spithoven, 2011).

In the light of the above arguments, the open innovation paradigm suggests that firms incorporate external as well as internal ideas to advance their technology. These ideas include knowledge from external institutions such as universities inside and outside the region where the firm is located, but a certain degree of absorptive capacity for university knowledge seems to be one of the main requirements for firms to absorb university knowledge through spillovers.

As pointed out above, one of the main findings of the empirical university spillover literature is that distance is a relevant factor for explaining the use (by firms) of academic knowledge produced in the same area or region where firms are located. However, several papers suggest that knowledge sourcing occurs at a variety of different spatial scales such as supra-regional and global connections that might be equally important to those in the region in order to get access to external knowledge sources (Arndt and Sternberg, 2000; Kaufmann and Todtling, 2001; Bathelt et al., 2004). Davenport (2005) reports some research that has analyzed how many firms do not acquire their knowledge from within geographically proximate areas, concluding that there are some factors that may work against geographically proximate knowledge-acquisition activities such as the role of foreign firms and multi-nationals, or firms working on some specific kind of technologies. Boschma (2005) argues that although geographical proximity facilitates interaction and cooperation for acquisition of knowledge, it is neither a prerequisite nor a sufficient condition for interactive learning to take place; other forms of proximity may frequently substitute for geographical proximity. Cargliu and Nijkamp (2012) recently explore the relationship between outward knowledge spillovers (measured as total factor productivity) and regional absorptive capacity for a sample of European regions,. Their result show that lower regional absorptive capacity increases knowledge spillovers towards surrounding areas, hampering the regions' capability to decode and efficiently exploit new knowledge, both locally produced and originating from outside. One of the main reasons explaining why some firms relies on proximity rather than in long distance sources of knowledge seems to be the grade of absorptive capacity: when firms' absorptive capacity is low, geographically proximate collaborations may be their only option. In contrast, high absorptive capacity enabling firms to collaborate for innovation at greater geographical distance (Drejer and Vinding, 2007; De Jong and Freel, 2010).

This literature suggests two important conclusions: first, distance is not an obstacle for many firms with high absorptive capacity to acquire knowledge from other regions. Second, the acquisition of knowledge from surrounding areas is easier for firms with lower absorptive capacity. This discussion leads to the following two hypotheses. Both hypotheses concern the influence of the absorptive capacity on the use of university knowledge produced inside and outside the region:

Hypothesis 1: The acquisition of codified knowledge in form of patents and papers produced by universities inside the region is negatively related to the absorptive capacity for academic knowledge of firms in the region.

Hypothesis 2: The acquisition of codified knowledge in form of patents and papers produced by universities outside the region is positively related to the absorptive capacity for academic knowledge of firms in the region.

The above hypotheses concern the firm capacity to acquire university knowledge, but academic knowledge is a flow; we need to take into account the other party in the game: universities. The question is to what extent the availability, quality or characteristics of the knowledge produced in universities stimulate or hinder the acquisition of inward and outward regional academic knowledge? In this respect, some empirical research has stressed the role of universities to encourage the flow of knowledge between universities and firms at regional level. Audrestch and Feldman (1996) find a positive relationship between ‘‘local university research funding’’ and ‘‘local industry value-added’’ at the state level. Their results indicate the relative economic importance of new knowledge to the location and concentration of industrial production. Zucker et al. (2002) relate the input “number of local research stars” to the output “number of new local biotech firms” and examine the variance in this relationship across geographic space at the economic region level. They find that the number of local stars and their collaborators is a strong predictor of the geographic distribution of US biotech firms in 1990. Branstetter (2001) identifies a positive relationship between ‘‘scientific publications from the University of California’’ and ‘‘patents that cite those papers’’, also at the state level. In another more recent paper Branstetter (2005) points out that the more rapid growth in the intensity with which U.S. patents cite academic science suggests a response to new technological opportunities created by academic research.

Other related literature on firm formation/location also suggests the importance of the characteristics of the academic knowledge for the spillovers to take place in the region. For example, Audretsch et al. (2004) focused on whether knowledge spillovers are homogeneous with respect to different scientific fields. They found that firms’ locational-decision is shaped not only by the output of universities (for

instance, students and research), but also by the nature of that output (that is, the specialized nature of scientific knowledge). Audretsch and Lehmann (2005) concluded that universities in regions with greater knowledge capacity and higher knowledge output also generate a larger number of technology start-ups. Several empirical papers in different spatial contexts point to the potential positive relationship between local university R&D expenditures and the number of newly created high technology firms (e.g. Harhoff, 1999 for Germany; Woodward et al., 2006 for US; Abramovsky et al., 2007, provide evidence on the extent business sector R&D activity is located near high quality university research departments in Great Britain; Acosta et al. 2011a found a significant relationship between some university outputs and new firm formation for the case of Spain).
According to this literature, we expect that a territorial environment with a well-established university presence increases the opportunities for the companies to access and absorb relevant new scientific knowledge more easily, in comparison with other companies located in regions with weak university capacities. At the same time, firms in regions with low technological and scientific opportunities will acquire academic knowledge elsewhere outside the region. This reasoning leads to the following two hypotheses:

Hypothesis 3: The acquisition of codified knowledge in form of patents and papers produced by universities inside the region is positively related to the university capacity to produce scientific and technological knowledge in the region.

Hypothesis 4: The acquisition of codified knowledge in form of patents and papers produced by universities outside the region is negatively related to the university capacity to produce scientific and technological knowledge in the region.

Model and variables

The basic model for testing our hypotheses relates the acquisition of university knowledge (UKA) by firms in a region to two main explanatory factors: the absorptive capacity (AC) and the availability of university knowledge in the region (U).
The regional function is given in general form as:

$$UKA_{it} = f(AC_{it}, U_{it}) \text{ for } i = 1, 2, ..., N$$

Where the subscripts "i" and "t" refer to region i and time t, respectively. We may call this equation the University Knowledge Acquisition Function (UKAF), and it concerns the activity in which firms in a region capture knowledge from inward and outward regional university knowledge (university knowledge produced in universities located in the region or elsewhere). To fully explain the knowledge acquisition we have extended this function in two ways:

- The model should control for the technological specialization and regional technological size. Although -to our knowledge- there is not empirical research on the effects of technological diversification (or specialization) on the acquisition of university knowledge, regions specialized in high technology might rely on external knowledge rather than on regional internal knowledge. For example, some authors (E.g. Klevorick, 1995, Acosta and Coronado, 2003, Laursen and Salter, 2004) suggest that in some industrial sectors, the relationship between universities and industrial innovation appears to be a tight one, such as in biotechnology, while in others such as textiles it appears to be weaker. On the other hand, European regions differ in their size. To avoid spurious correlation the model must control by the technological size of inward outward knowledge (using for example the size of the patent portfolio in each region).
- Regions are grouped in countries and consequently some correlation is expected across regions of the same country. For example, national innovative measures, incentives -or more general firms' policies- influencing the regions of the whole country. The presence of higher-order hierarchical structures with different characteristics (regions are grouped in countries) point to the multilevel nature of the factors influencing the acquisition of university knowledge.

We may reformulate the initial model by including these additional factors in an extended UKAF:

$$UKA_{git} = f(AC_{git-2}, U_{git-2}, S_{git-2}, Z_{git-2}, e_{gt}, u_{git}) \text{ for } i = 1,2,...,N \;\; g = 1,2,...,G$$

Where g indexes the group or cluster. S controls for the technological specialization of the region and Z for its size. e is an unobserved cluster-effect capturing the regional influences of the group (country) on the regional acquisition of inward and outward knowledge and u is the idiosyncratic error. Finally, the empirical estimations also include some dummies to capture temporal fixed effects. All the explanatory variables consider a two-year lag.2

The following paragraphs explain how we have measured our variables.

Dependent variables. We consider two dependent variables in two separate models:

- The acquisition or use of inward regional university knowledge is captured by the number of citations in firms' patents to universities located in the same region where the firm is established.
- The acquisition or use of outward regional university knowledge is captured by the number of citations in firms' patents to universities located outside the region where the firm is established.

[2] Two, three or even five-year lags between dependent and independent variables are usually taken into account in the patent literature, but in this case the specification of lag structures should not be an important concern because the explanatory variables are supposed to be stable over the years.

Independent variables:

- Absorptive capacity (AC). The empirical literature on absorptive capacity has to a large extent limited itself to the amount of R&D expenditures or presence of an R&D unit as a measure of absorptive capacity both at firm and at regional level. Other popular indicators of absorptive capacity include human resources, and networks. In this paper we use R&D efforts as a viable proxy of absorptive capacity (firms' R&D as percentage of GDP -gross domestic product-). The original paper by Cohen and Levinthal (1990) used firm-based R&D data as proxies for absorptive capacity in the empirical section of their paper. Subsequent extensive evidence has used firm R&D to analyse the firms' capability to access knowledge from external sources (e.g. seminal papers such as Kim, 1997, and Kodama, 1995, stressed the crucial role of a firm's internal R&D in determining its ability for the acquisition and assimilation of external knowledge).
- Presence in the region of university technological opportunities (U). We capture the capacity of universities to produce quality patents in each region the regional 'Higher Education R&D' expenditure as percentage of regional GDP. This is a resource variable to proxy for the strength of the university system to produce outputs. We expect that greater effort in university R&D should lead to more university outputs that could increase the opportunities for firms to acquire and exploit this knowledge.
- To control for the regional specialization (S) we calculate a similar measure to the revealed technological advantage index (Soete and Wyatt, 1983): TAI= $\frac{P_{ij} / \sum_{s=1}^{S} P_{is}}{\sum_{i=1}^{N} P_{is} / \sum_{i=1}^{N} \sum_{s=1}^{S} P_{is}}$, where $P_{is} / \sum_{s=1}^{S} P_{is}$ is the number of patents of region i in sector j over the number of patents of region i in all sectors; $\sum_{s=1}^{N} P_{is} / \sum_{i=1}^{N} \sum_{s=1}^{S} P_{is}$ is the number of patents of all regions in sector s over the total number of patents. To construct the index we use eight sections of the International Patent Classification (IPC) (see the bottom of Table 2).
- To control for the size of the region (Z) we include the number of firms' patents in each region. This variable prevent from obtaining spurious relationships (as regions with more patents are expected to have more citations).

For estimating the models, we apply a conditional fixed and random effects negative binomial estimator in which we assume that units (regions) are positively correlated within clusters (countries). Then, the econometric estimations are in the framework of the cluster count data models. The decision to use a two-level hierarchical analysis (regions clusters in countries) has two main objectives: (a) to evaluate the unobserved heterogeneity—along with the fixed effects—of the regional acquisition of knowledge; the inclusion of random effects in the model considers that there is natural heterogeneity across regions of the same country;

(b) to correctly estimate the confidence intervals, taking into account the intra regional correlation of regions in of the same country. Failures to take into account the clustering of data result in serious biases (see, for example, Moulton, 1990; Antweiler, 2001; Wooldridge, 2003, 2006).
To summarize, the empirical base models are as follows.

- A negative binomial model with a hierarchical data structure (regions grouped into countries) for analyzing the acquisition of inward regional knowledge.
- A negative binomial model with a hierarchical data structure (regions grouped into countries) for the acquisition of outward regional knowledge.

The previous paragraphs describe the base specifications. However, taking into account the structure of our sample, the nature of the data, and other considerations such as the number of zeros in the sample, we have considered additional models:

- A negative binomial model and a zero inflated negative binomial model with a pooled data structure and clustered robust standard errors (the clusters are countries) for the acquisition of inward regional knowledge (Table 4)
- A negative binomial model and a zero inflated negative binomial model with a pooled data structure and clustered robust standard errors (the clusters are countries) for the acquisition of outward regional knowledge (Table 4)

Data

The data collection process was designed by the Institute for Prospective Technological Studies (IPTS) in 2009. An international consortium of researchers from the University of Newcastle, Incentim and the Centre for Science and Technology Studies (CWTS) were responsible for implementing the data collection. Figure 1 may help visualising data construction. The EPO Worldwide Patent Statistical Database (PATSTAT) database was used to compile a dataset of 228.594 direct EPO patents applied for in the period 1997-2007. The team then identified 10,307 patents with university references, i.e. citations to patents applied for by universities or to WoS scientific articles, signed by authors with a single university affiliation. Actually, this single-university affiliation criterion is the main limitation of the database, due to resource constraints, and implies that both the number of patents with references and the share of papers within university references are underestimated.

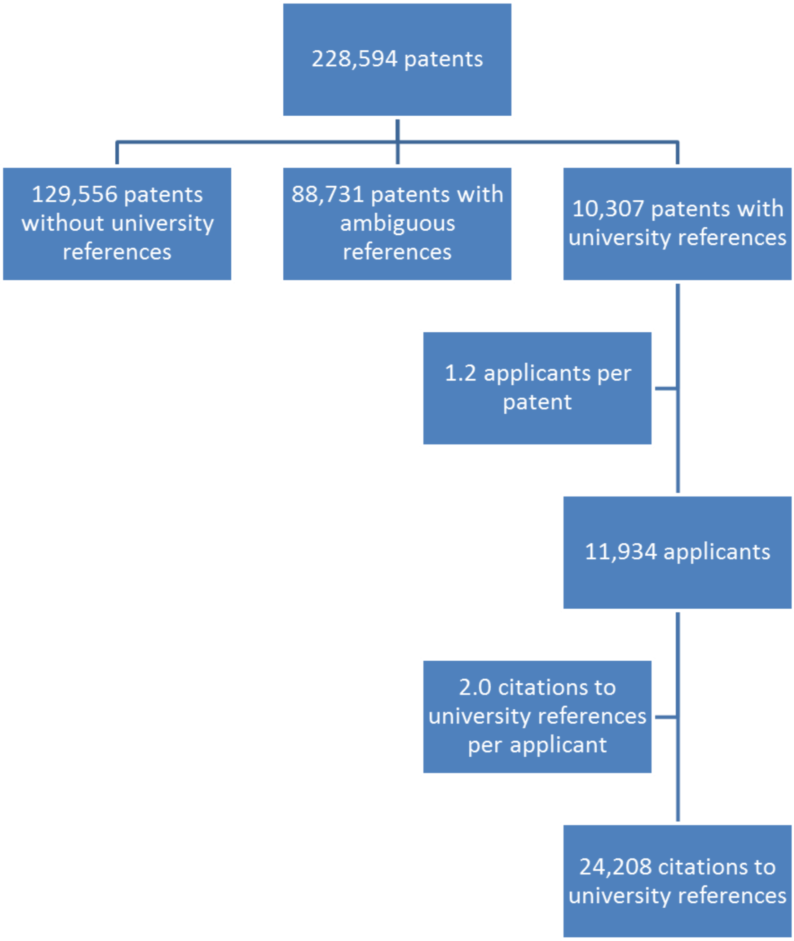

Figure 1. University references in direct EPO patents, 1997-2007

Each patent had an average of 1.2 applicants, resulting in a total of around 12,000 applicants.; and each applicant cited an average of 2 university references, so the starting number of citation to university references was slightly over 24,000. In order to match the NUTs II region of the citing applicant and the cited university, we excluded citations by non-EU27 applicants and a few EU27 applicants without regional information (Figure 2). In order to test our hypotheses, we excluded applicants other than firms, resulting into a total of some 13,000 citations. For these, we could check whether there was a match between applicant region and region of a citation from a university: 2 percent produced a positive match.

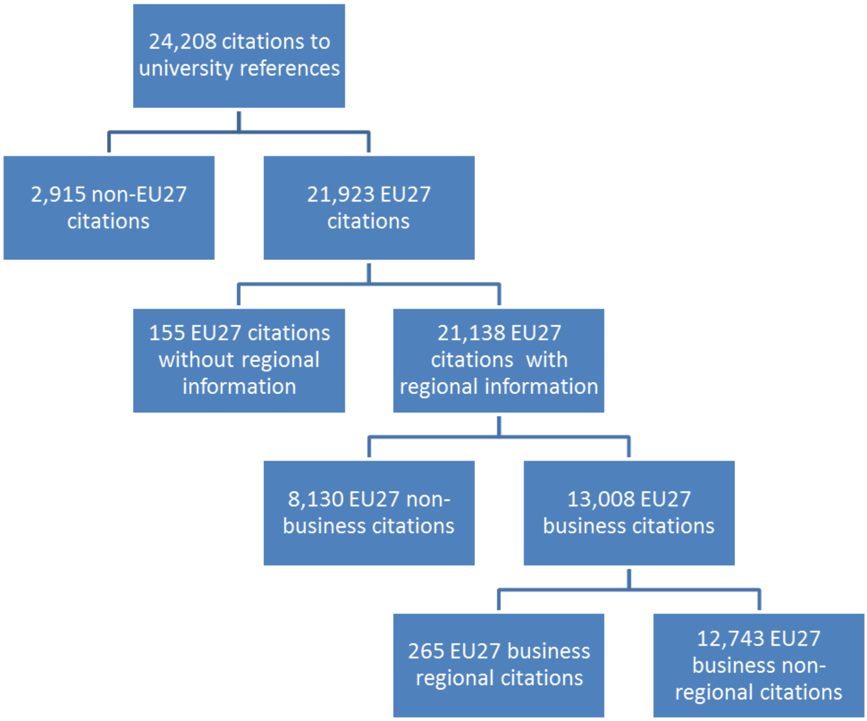

Figure 2. Citations to university references in direct EPO patents, 1997-2007

We aggregated patent and citation counts per region and year to produce a panel that was linkable to Eurostat regional R&D statistics. This results in a sample of 2,365 observations (Figure 3); however, there are 1,181 observations in which there is not any patent belonging to firms. The consequence is that we finally count on fewer observations. The estimated models in the next Section include firm and university R&D intensity as explanatory variables. As there are many missing data for these variables at regional level, this results in a new reduction in the number of observation to 503 for 22 countries in the UE27 from 1997 to 2007. The number of patents drops to around 4,000 and that of citations to universities to around 6,000, of which a 2 percent are still regional citations.

We mentioned in section 3 that the nature of the data suggests the specification of grouped and pooled models. Tables 1 and 2 show the descriptive statistics for each type of model. Note that the use of the fixed effects estimator requires that countries with only one observation is omitted; that's why there is a different number of observations depending on the type of model (Figure 3).
The two dependent variables show a remarkable different behaviour. In the case in which we have 464 observations, the acquisition of university knowledge from the region (inward) by firms takes into account 388 observations with zero citations, and 76 observations with one or more citations (Table 1). In models

with 499 regions, the outward acquisition of knowledge by firms has only five observations with zero citations and 494 with one or more citations (Table 2).

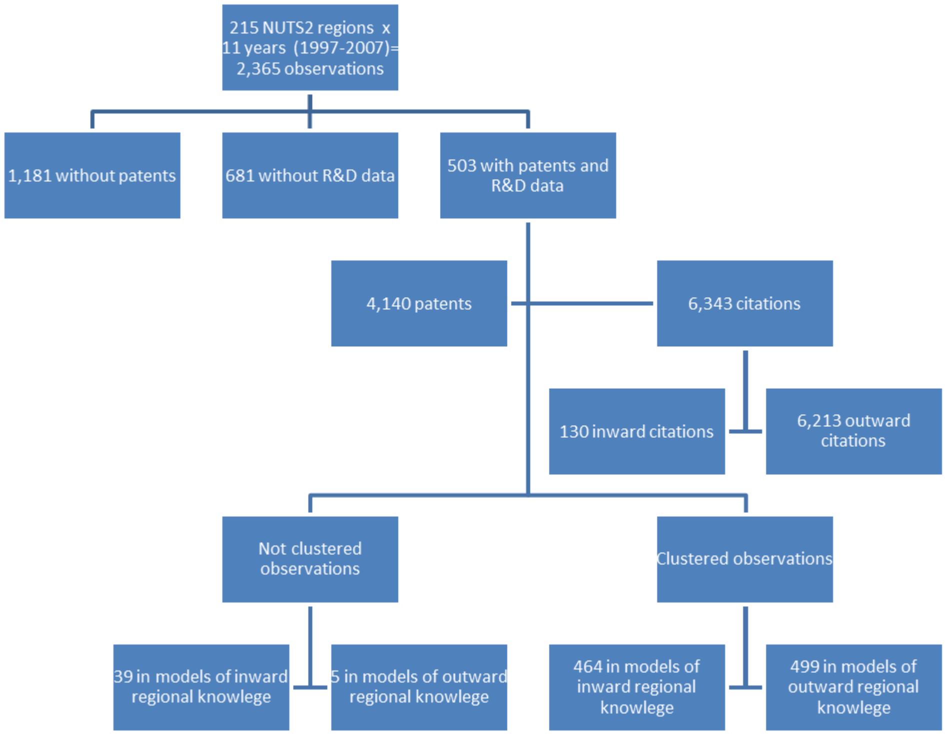

Figure 3. The panel

Table 1

Descriptive Statistics
464 observations

	Mean	*Std. Dev.*	*Min*	*Max*
Acq. Inward reg. know	0.280	0.763	0	6
A=Firms' R&D/GDP	1.135	0.890	0.04	6.83
U=Universities' R&D/GDP	0.395	0.205	0.01	1.30
Numberpatents	8.933	17.515	1	151
speA (1)	0.931	0.690	0	3.83
speB	0.684	0.960	0	7.42
speC	0.693	0.595	0	2.17
speD	0.313	1.504	0	22.19
speE	0.294	1.320	0	17.20
speF	0.505	1.211	0	8.57
speG	0.598	0.618	0	3.94
speH	0.447	0.738	0	5.15

Table 2

	Descriptive Statistics 499 observations			
	Mean	*Std. Dev.*	*Min*	*Max*
Acq. Outward reg. know	12.790	26.366	0	243
A=Firms' R&D/GDP	1.136	0.902	0.04	6.83
U=Universities' R&D/GDP	0.398	0.225	0	1.32
Numberpatents	8.531	16.988	1	151
speA (1)	0.917	0.698	0	3.83
speB	0.698	1.002	0	7.42
speC	0.693	0.597	0	2.17
speD	0.291	1.452	0	22.19
speE	0.308	1.385	0	17.20
speF	0.513	1.231	0	8.57
speG	0.581	0.610	0	3.94
speH	0.444	0.733	0	5.15

Figure 4 shows that the number of citations has remained quite stable through time. It has oscillated around almost a horizontal line in the case of both inward and outward citations during the period of observation. Actually, the share of regional over total citations has also moved around the average of 2 percent without clear upward or downward patterns.

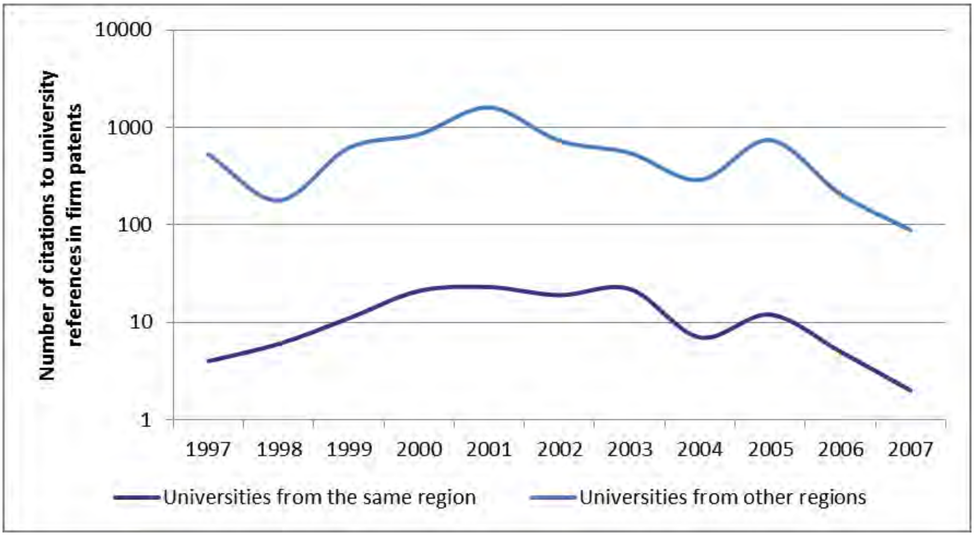

Figure 4. Stability on the evolution of firm citations to university references

On the contrary, Figure 5 illustrates that cross-sectional variation is apparently more important. If we compare the top ten regions in number of inward versus outward citations (upper and lower parts of the figure, respectively), only three appear in both rankings: Île de France, London and Berlin. The rest are different, suggesting that the processes of university knowledge acquisition depend on varied factors according to the inward or outward nature of the flow. It is also an empirical validation of the interest of the topic, raised in the introduction.

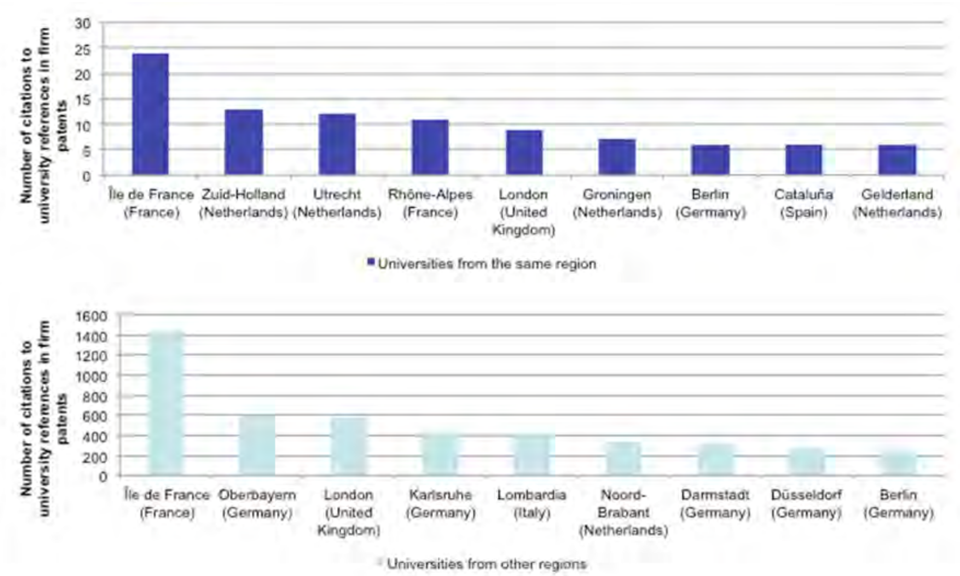

Figure 5. Cross-regional variation in firm citations to university references: top regions in number of citations

Econometric results

Baseline results

This section presents the results for both analysis (inward and outward acquisition of knowledge) and taking into account two different structures of the data (hierarchical and pooled):

Firstly, Table 3, Columns 1-2 and 4-5, show the estimated models for the acquisition of inward and outward knowledge following the hierarchical data structure (applying a fixed and random effects estimator for each one). In order to compare the results of different estimators, we have used the same number of observations (464 for the inward knowledge acquisition and 499 for the outward).

Secondly, Table 3, Columns 3 and 6, show the pooled models for the same number of observations. Given the nature of the dependent variable, we provide the ZINB estimation when the dependent variable is the acquisition of inward knowledge (which has many zeros), and a NB when the dependent variable is the acquisition of outward knowledge (these are the preferred models according to the Vuong statistic).

Results about variables affecting inward university knowledge are taken from Column 3 because likelihood ratio test suggest models with pooled data (Column 3) are preferred to models with hierarchical structure (Columns 1-2). Column 3 shows that the absorptive capacity of firms in the region does not play any role in determining the use of scientific and technological university knowledge generated in the same region of the firm's location. There is no evidence in favour of Hypothesis 1.

Columns 4-5 show that the firms' absorptive capacity of the region determines the use of outward university knowledge (grouped data preferred to pooled data according to LR test). That is, regions with greater effort in private R&D have a greater absorption of scientific and technological university knowledge from outside the region (from other countries or other regions in the same country). Hence, Hypothesis 2 is confirmed.

Concerning the influence of the university capacity of the region to produce spillovers, Column 3 shows that the use of scientific and technological university knowledge by firms from the same region is positively related to the university capacity of the region. This means that the greater the R&D effort in the universities of the region, the larger the use of scientific and technological knowledge from the own regional universities, i.e. the evidence supports Hypothesis 3.

Columns 4-5 give us the opportunity to contrast the effect of university capacity of the region on the acquisition of outward university knowledge. University capacity of the region is negatively related with de acquisition of university knowledge from outside the region by private firms, and consequently there is evidence in favor of Hypothesis 4.

Table 3

Dependent Variable: UKA (University knowledge Acquisition)												
	I. Acquisition of inward regional knowledge						II. Acquisition of outward regional knowledge					
	Negative binomial models for grouped data				ZINB model for pooled data		Negative binomial models for grouped data				NB model for pooled data	
	1 FE		2 RE		3 Robust Std Err Adjusted (country)		4 FE		5 RE		6 Robust Std Err Adjusted (country)	
Cons	-18.715		-21.740		-16.595	**	-1.156	**	-1.216	**	-0.523	**
A=Firms' R&D/GDP	-0.347	*	-0.340	*	-0.291		0.078	**	0.088	**	0.049	
U=Universities' R&D/GDP	2.460	**	2.265	**	2.137	**	-0.330	**	-0.258	*	0.138	
Numbpatents	0.017	**	0.018	**	0.016	**	0.022	**	0.021	**	0.040	**
speA (1)	0.742	**	0.866	**	1.595	**	0.459	**	0.474	**	0.484	**
speB	0.290		0.292		0.282	**	0.161	**	0.163	**	0.131	**
speC	1.255	**	1.190	**	-0.042		0.872	**	0.874	**	0.888	**
speD	-0.042		-0.044		0.190		0.014		0.017		0.041	**
speE	0.142		0.147		-0.072		0.021		0.023		0.019	
speF	0.267		0.195		0.265		0.080	**	0.079	**	0.089	*

speG	0.433		0.363		0.315		0.506	**	0.524	**	0.527	**
speH	0.578	**	0.503	**	-0.011		0.311	**	0.312	**	0.283	**
Ln_r			3.122						2.464			
Ln_s			2.160						3.306			
Inflation model (logit)												
Cons					1.583							
speA (1)					1.134							
speB					-0.270							
speC					-2.849	**						
speD					0.289							
speE					-0.703							
speF					0.295							
speG					0.515	*						
speH					-1.657							
Number of obs	464		464		464		499		499		499	
Number of groups	9		9		9		18		18		18	
Wald chi2	115.20	**	122.66	**			2746.73	**	2823.93	**		
Loglikelihood	-201.35		-230.51		-220.41		-1334.04		-1417.03		-1314.75	
LR Test Panel vs Pooled			1.63						57.44	**		

Notes:
(1) IPC Sections to construct the specialization indexes (spe): A Human Necessities; B Performing Operations; Transporting; C Chemistry; Metallurgy; D Textiles; Paper; E Fixed Constructions; F — Mechanical Engineering; Lighting; Heating; Weapons; Blasting: G Physics; H Electricity.
- **, * denote that the coefficients are statistically different from zero at the 5% and 10% levels, respectively.
- All models include year dummies for 1997 to 2007.
- VIF suggests no signs of multicollinearity.
- Likelihood ratio test favours Poisson against NB in Models 3 and 6
- Vuong statistics favours ZINB against NB in Model 3 and NB against ZINB in Model 6.

Robustness check

The fixed effects panel models shown so far are computable only for the 464 and 499 observations used in the previous section. However, in the rest of the models, using the same number of observations is an imposition to facilitate comparison. As robustness check, we have estimated the same specifications as in previous section but without restrictions in the number of observations for each model. The advantage of not imposing any restriction is that we can count on more data for the estimations; however, the comparisons for selecting models are now more difficult. The number of observations increases to 503 in the random effects models, ZINB and NB. Table 4 provides the descriptive statistics.

Table 4

Descriptive Statistics
503 observations

	Mean	*Std. Dev.*	*Min*	*Max*
Acq. Inward reg. know	0.258	0.737	0	6
Acq. Outward reg. know	12.704	26.278	0	243
A=Firms' R&D/GDP	1.128	0.903	0.02	6.83
U=Universities' R&D/GDP	0.396	0.225	0	1.32
Numberpatents	8.473	16.933	1	151
speA (1)	0.917	0.711	0	3.83
speB	0.698	1.003	0	7.42
speC	0.693	0.600	0	2.17
speD	0.412	3.113	0	62.12
speE	0.305	1.379	0	17.20
speF	0.509	1.227	0	8.57
speG	0.577	0.610	0	3.94
speH	0.442	0.732	0	5.15

For these 503 observations the preferred model for inward UKA is ZINB with pooled data structure (presented in Table 5, Column 3). The preferred model for outward UKA is NB with hierarchical structure (presented in Table 5, Column 6). These new estimations, which have not been forced to use the same number of observation, confirm the previous results; the hypotheses rejected and non-rejected are just the same as in Section 5.1.

Table 5

Dependent Variable: UKA (University knowledge Acquisition)						
	I. Acquisition of inward regional knowledge			II. Acquisition of outward regional knowledge		
	Negative binomial models for grouped data		ZINB model for pooled data	Negative binomial models for grouped data		NB model for pooled data
	1 FE	2 RE	3 Robust Std Err Adjusted (country)	4 FE	5 RE	6 Robust Std Err Adjusted (country)
cons	-18.715	-21.893	-16.987**	-1.156**	-1.217**	-0.527 **
A=Firms' R&D/GDP	-0.347 *	-0.421**	-0.311	0.078**	0.091**	0.057
U=Universities' R&D/GDP	2.460**	1.973**	1.943**	-0.330**	-0.259 *	0.132
Numbpatents	0.017**	0.018**	0.015**	0.022**	0.021**	0.039 **
speA (1)	0.742**	0.850**	1.774**	0.459**	0.469**	0.478 **
speB	0.290	0.304 *	0.334**	0.161**	0.163**	0.128 **
speC	1.255**	1.195**	0.204	0.872**	0.873**	0.885 **
speD	-0.042	-0.031	0.188	0.014	0.005	0.007
speE	0.142	0.132	-0.089	0.021	0.022	0.018
speF	0.267	0.170	0.331	0.080**	0.083**	0.095 **
speG	0.433	0.425 *	0.428	0.506**	0.522**	0.522 **
speH	0.578**	0.545**	0.052	0.311**	0.314**	0.285 **

Ln_r			2.556						2.411			
Ln_s			1.488						3.210			
Inflation model (logit)												
cons					0.964							
speA (1)					1.254							
speB					-0.160							
speC					-2.249	**						
speD					0.198							
speE					-0.545							
speF					0.462							
speG					0.451							
speH					-1.472							
Number of obs	464		503		503		499		503		503	
Number of groups	9		22		22		18		22		22	
Wald chi2	115.20	**	122.40	**			2746.73	**	2832.37	**		
Loglikelihood	-201.35		-237.10		-227.67		-1334.04		-1425.57		-1323.28	
LR Test Panel vs Pooled			3.28	**					58.84	**		

Notes:

(1) IPC Sections to construct the specialization indexes (spe): A Human Necessities; B Performing Operations; Transporting; C Chemistry; Metallurgy; D Textiles; Paper; E Fixed Constructions; F — Mechanical Engineering; Lighting; Heating; Weapons; Blasting: G Physics; H Electricity.

- **, * denote that the coefficients are statistically different from zero at the 5% and 10% levels, respectively.
- All models include year dummies for 1997 to 2007.
- VIF suggests no signs of multicollinearity.
- Likelihood ratio test favours Poisson against NB in Models 3 and 6.
- Vuong statistics favours ZINB against NB in Model 3 and NB against ZINB in Model 6.

Conclusions

In this paper we argue that the knowledge that firms in a region can acquire from university spillovers is a function of both the absorptive capacity of the firms developed by investing in knowledge, and the opportunities for university spillover. To test our hypotheses we put forward an external knowledge acquisition function which explains the factors affecting the regional inward and outward acquisition of university knowledge by firms.

Our models yield to reject hypothesis 1. Hypotheses 2, 3 and 4 are not rejected. According to these findings, absorptive capacity is not relevant in explaining the acquisition of inward scientific and technological university knowledge; however, regional absorptive capacity plays a relevant positive effect in the acquisition of outward university knowledge. Regarding the other relevant variable in the models, university opportunities for spillovers in the region have a positive effect on the acquisition of local knowledge by firms from the same region, and a negative influence in the acquisition of outward university regional knowledge.

These findings have some relevant policy implications. Considering the objective of policy makers, we can divide implications into two types:

- If the objective of regional government is encouraging the use of university knowledge produced in the region (by firms established in the region), our results suggest that the only way is the stimulation of the supply side, that is the investment in university scientific and technological knowledge to produce regional opportunities. However, this has a trade-off: it also decreases the acquisition by firms of university knowledge produced outside the region. Hence, it opens the risk of lock-in effects by closing regions to external knowledge.
- If the objective is improving the competitiveness of local firms (in the sense that they could understand and incorporate university knowledge from elsewhere), our results suggest that absorptive capacity is the variable to spur. In addition, it has a dual role, since it compensates the negative effect of high university R&D capacity on outward knowledge acquisition.

Future research would include increasing the number of cited university references in order to break down the data by type of cited literature (patent or non-patent literature) or origin of the citation (examiner or applicant). For the time being, the number of regional citations is too scarce to produce meaningful results. Another line would be to face the traditional geographic approach to patent citations –the role of distance– versus this paper's approach –the role of regional borders– and ask which one matters more: distance or borders. Adding more measures of firms absorptive capacity and university supply capacity would be enriching, but would require previous research about how they can be defined at regional level that is outside the scope of this paper. It would be also worth investigating whether having engaged into actual cooperation with universities shapes citation patterns. Replicating the analysis at NUTs III level would be potentially interesting, but regions at that level have less margin for implementing their own policies, the number of regional citations would be lower and R&D statistics less available. Finally, a complementary approach should retrieve information from full-text rather than front-page citations, but this would require much manual work and be enormously costly for such a large sample.

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