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Acosta, Manuel; Coronado, Daniel; León, M. Dolores; Martinez, M. Ángeles

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The production of university technological knowledge in European regions: evidence from patent data

Manuel Acosta (*)
Daniel Coronado
M. Dolores León
M. Ángeles Martínez

All: Universidad de Cadiz - Facultad de CC Economicas y Empresariales
Duque de Najera, 8 Cadiz Cadiz 11002
Spain

(*) Correspondence to: manuel.acosta@uca.es

daniel.coronado@uca.es

marilo.leon@uca.es

mariangeles.martinez@uca.es

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Abstract: This paper explores the European regional distribution of the production of new technological knowledge generated by universities, as measured by patent counts. The empirical basis for this study is a unique panel data set of 4,580 European university patents from 1998 to 2004. Our main findings were a strong regional and sectoral concentration of patents, and no average relation between university technological specialization and industrial specialization. Furthermore, our results suggest that variations in regional R&D funding do affect patenting activities in regions, with elasticities showing constant returns to scale, but no evidence was found regarding the industrial potential of the region encouraging the production of new university technological knowledge.

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Key words: European regions, knowledge production, university patents, technological specialization.

JEL codes: O33, O32

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La producción de conocimiento tecnológico universitario en las regiones europeas: evidencia a partir de las patentes

En este artículo exploramos la distribución regional en Europa de la producción de conocimiento tecnológico generado en las universidades, medido a través de las patentes. La base empírica para este estudio consiste en un conjunto de 4.580 patentes universitarias europeas con fecha de solicitud desde 1998 hasta 2004. Nuestros principales resultados se resumen en una fuerte concentración regional y sectorial de patentes, con una relación media inexistente entre especialización tecnológica universitaria y especialización industrial. Además los modelos sugieren que variaciones en los fondos regionales de I+D influyen en la producción de patentes universitarias, con elasticidades que muestran rendimientos constantes a escala; sin embargo, no se obtuvieron evidencias de la capacidad del potencial industrial de la región para estimular la producción de conocimiento tecnológico universitario.

Palabras clave: Regiones europeas, producción de conocimiento, patentes universitarias, especialización tecnológica.

La production de la connaissance technologique universitaire dans les régions européennes: des preuves provenant des données sur les brevets.

Acosta et al.

Cet article cherche à examiner la distribution régionale européenne de la production de la nouvelle connaissance technologique universitaire en fonction du nombre de brevets. La base empirique de cette étude est un unique ensemble de données provenant d'une enquête par panel pour 4.580 brevets déposés par des universités européennes entre 1998 et 2004. Il en a résulté principalement une forte concentration régionale et sectorielle des brevets et aucun rapport moyen entre la spécialisation technologique universitaire et la spécialisation industrielle. Qui plus est, les résultats laissent supposer que la variation du financement régional pour la R et D influent sur les activités régionales brevetables, dont les elasticités montrent des rendements d'échelle constants, mais il n'y avait pas de preuves quant à une corrélation étroite entre le potentiel industriel de la région et la production de la nouvelle connaissance technologique universitaire.

Régions européennes / Production de la connaissance / Brevets universitaires / Spécialisation technologique

Classement JEL: O33; O32

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Die Produktion von universitärem technischem Wissen in europäischen Regionen: Belege von Patentdaten

Manuel Acosta, Daniel Coronado, M. Dolores León and M. Ángeles Martínez

Abstract:

In diesem Beitrag wird die regionale Verteilung der Produktion von neuem technischem Wissen, das von Universitäten in Europa erzeugt wird, anhand der Anzahl der Patente untersucht. Die empirische Grundlage für diese Studie bildet ein eindeutiger Paneldatensatz mit 4580 Patenten europäischer Universitäten aus der Zeit von 1998 bis 2004. Unsere wichtigsten Ergebnisse waren eine ausgeprägte regionale und sektorale Konzentration der Patente sowie keine durchschnittliche Beziehung zwischen der technischen Spezialisierung der Universitäten und der industriellen Spezialisierung. Darüber hinaus weisen unsere Ergebnisse darauf hin, dass sich Abweichungen in der Finanzierung der regionalen Forschung und Entwicklung auf die Patentaktivitäten in den Regionen auswirken, wobei die Elastizitäten einen konstanten Skalenertrag aufweisen. Hingegen wurden keinerlei Belege hinsichtlich des industriellen Potenzials der Region zur Förderung der Produktion von neuem technischem Wissen der Universitäten gefunden.

Key words:

Europäische Regionen

Wissensproduktion
Universitäre Patente
Technische Spezialisierung
JEL codes: O33, O32

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1. Introduction

In a modern conception, universities are increasingly viewed as active contributors to technological development and regional economic growth. The importance of universities in encouraging regional technological change has been reported in some well-known studies of economically successful regions (MARKUSEN *et al.*, 1986; SAXENIAN, 1994; STERNBERG and TAMÁSY, 1999; WEVER and STAM, 1999) and in studies that have used the national/regional systems of innovation as a framework (LUNDVALL *et al.,* 2002; GOLDFARB and HENREKSON, 2003; GITTELMAN, 2006). Regional innovation systems are a suitable framework for understanding the general innovation process at a regional scale, and they also provide some relevant clues to assist in understanding the role of universities and the knowledge production of universities in a regional context. Universities are assumed to accomplish a number of different functions in a regional innovation system. FRITSCH and SLAVTCHEV (2007) emphasized some of these functions. By conducting R&D activities, universities generate and accumulate knowledge (scientific and technological). One of the most important channels for the transfer of academic knowledge into the private sector is the teaching and training of students. Academic knowledge can also disseminate through R&D cooperation with private sector firms or by providing innovation-related services. Moreover, universities may serve as “incubators” for knowledge-intensive spin-offs. Finally, scientific outputs and informal relationships can be important ways of transferring academic knowledge to the private sector. Some of the ideas in the innovation system concept are included in the “triple helix” model (ETZKOWITZ and LEYDESDORFF, 1997, 2000; LEYDESDORFF, 2000). The thesis of the triple helix is that the university can play an essential role in the process of innovation, and thus strengthen knowledge-based societies. In these types of models, different possibilities are proposed concerning the relationship between the institutional spheres—university, industry, and government—that may help to generate alternative strategies for

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"economic growth and social transformation" (ETZKOWITZ and LEYDESDORFF, 2000). From a regional perspective, in the triple helix, academia plays a role as a source of innovation for regional development. ETZKOWITZ and KLOFSTEN (2005) summarized the basic elements of the triple helix model and its importance from a regional perspective: "First, it presumes a more prominent role for the university in innovation, on a par with industry and government in a knowledge–based society. Second, there is a movement toward collaborative relationships among the three major institutional spheres in which innovation policy is increasingly an outcome of interaction rather than a prescription from government. Thirdly, in addition to fulfilling their traditional functions, each institutional sphere also 'takes the role of the other' operating on a y-axis of their new role as well as an x-axis of their traditional function. An entrepreneurial university, taking some of the traditional roles of industry and government, is the core institution of an Innovating Region".

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The positive effects of universities in regions may occur through a variety of university outputs that potentially have important impacts on regional economic development, as noted previously. In this paper we focus on one of these outputs: the generation of university patents. University patenting may have an influence on innovation in regions in two different but complementary ways. On the one hand, there is a potential direct contribution when a university produces useful new patented technological knowledge with potential applications to the industrial processes. This new patented knowledge may be transferred to private firms through licensing, by increasing private innovation, and by the inducement of regional economic growth. Furthermore, patents are valuable as their licensing helps to generate employment, especially among graduates, when a spin-off firm is created to exploit the patent. On the other hand, the production of a patent may have an indirect contribution to regional innovation due to the flow of technological knowledge between universities and firms. This flow of knowledge can take place through a variety of channels of interaction between academics and firms (when reading the patent, or via direct conversation or informal meetings with the inventors, etc.)[1] The flow of knowledge has important potential benefits for regions because of *spillovers* from university to industry (see for instance, AGRAWAL and COCKBURN, 2003; ANSELIN *et al.*, 1997, 2000; CALDERINI and SCELLATO, 2005; FISCHER and VARGA, 2003; JAFFE, 1989; JAFFE *et al.*, 1993; MAURSETH and VERSPAGEN, 2002; VERSPAGEN and SCHOENMAKERS, 2000). The proliferation of a consistent literature illustrating the importance of physical proximity for knowledge flows and for the promotion and development of innovation, allied with the high degree of self-government enjoyed by many European regions, makes it clear that the study of knowledge from universities is relevant not only in national or supranational contexts but also at the regional level. However, although most of the studies that stress the importance of universities at a regional scale have analysed the effects of scientific and technological knowledge on the innovation of firms, little is known about the causes. For instance, are there any particular (economic) characteristics of regions that encourage the production of technological knowledge in their universities? As we will point out below, the bulk of the empirical literature on the characteristics of a university's technological knowledge and the causes of technology generation in universities (measured by patents) is focused on countries, universities, laboratories, or individual inventors from universities. Very few papers have aimed to analyse this issue at a regional scale. Nevertheless, universities in the same country are not homogeneous institutions; the financial resources, the level of regional development, the industrial structure of regions, legal regulations, and other particular characteristics of the regions can affect the motivation and capacities of universities to produce new technological knowledge. As BOUCHER *et al.*, 2003, reported in their case studies review of the role of universities in regional development, the interactions of institutional and social factors can foster or hinder the contributions of universities to their region's development. This is the main argument for carrying out this research in the case of the European regions. The purpose of this paper is to address these significant

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issues. We will consider, from a regional point of view, the magnitude, technological characteristics, regional peculiarities, and explanatory causes of the direct contribution of universities in European regions to the development of industrial technology. More specifically, we will seek to answer the following research questions.

What is the distribution of the production of university technological knowledge across European regions?

What relationship exists between the regional technological specialization of the universities and the economic specialization?

Finally, we investigate which factors determine the regional development of university technological knowledge, in particular R&D funding. The answer to this question is especially relevant because the identification of these factors may help to implement regional policies that encourage the production of industrial knowledge by universities.

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The empirical basis for this study is a unique panel data set of 4,580 family patents (patents that cover the same inventions) from the Derwent Innovation Index. We have considered the family patent if it includes at least one European university patent, covering the years from 1998 to 2004. This is an original data set that was organized and regionalized using Nomenclature of Territorial Units for Statistics (NUTS) II. Our empirical methodology involves two parts. First, we undertook a descriptive analysis of regionalized data to map the technological knowledge production generated from European universities, and to answer some of the research questions. In the second step, we carried out an econometric analysis (a knowledge production function) to test the importance of the classical inputs (regional university R&D) and the demand factors (the industrial potential of the regions) in the process of generating new university technological knowledge across European regions.

This paper contributes to the existing literature in several ways. First, it presents an overview of how university patenting is spread across European regions. Second, although some studies focus on the determining factors in the production of knowledge (measured by patent counts) by countries, universities, etc., there are none that discuss the European regions as a whole. Third, most of the European regions have enough autonomy to organize their own systems of innovation. Therefore, a better understanding of the characteristics and causes of the technological generation of new knowledge in universities may help to define policies that support regional technological development.[2]

The paper is organized as follows. In the first section, we review some empirical papers focusing on university patents and their determining factors. Next, using patent counts, we explore some of the characteristics of the production of new knowledge by universities in the European regions. In the following sections, using our econometric specification, we test how regional spatial inputs and demand factors are related to the production of university patents. The main conclusions and some policy implications are drawn at the end of the paper.

2. Literature review

Previous research on the generation of university patents and their explanatory causes has mainly related to US universities. Recently, there has been growing concern about this issue in Europe, but the evidence remains scarce. Little is known about the effects of regional peculiarities on the production of patents by universities. In the following paragraphs, we highlight some of the conclusions of the recent empirical literature.

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One of the more relevant studies on the characteristics and explanatory causes of university patenting is by HENDERSON *et al.*, 1998, who compared the US universities' patents for the period 1965–1988. Regarding explanatory causes of the evolution of university patents, they emphasized three essential aspects: the legal framework, or changes in the federal laws that facilitate patent applications by universities (MOWERY *et al.*, 2001, put this finding in doubt); increases in industrial funds destined to support university research; and the increase in the numbers of interface centres and institutions. COUPÉ, 2003, estimated a production function for university patents by means of empirical count models, in which the principal explanatory factors were academic expenditures on R&D, and the institutional factors considered previously by HENDERSON *et al.*, 1998. The results of this study confirmed the evidence on the institutional effects and the significant influence of R&D expenditure on the output of university patents. In addition, COUPÉ, 2003, found some indications of constant returns to scale at the institutional level. However, once fixed effects are controlled for, he found much smaller coefficients, indicating decreasing returns to scale. PAYNE and SIOW, 2003, discussed the effect of federal funding on university patents. After analysing the data under different specifications, they suggested that when universities receive more funding, they will produce more patents at the margin. As possible explanatory causes of the mechanisms by which universities develop patents, these authors suggested know-how (the accumulation of previous patents or experience in the particular field), the personnel dedicated to technology transfer, and contractual links with companies that patent. In two similar papers, FOLTZ *et al.*, 2000, 2003, examined the production of patents in ag-biotech sectors for US universities. In their first study, they used a static count data model to stress the role of the technology transfer offices and star scientists. In their second paper, they estimated a panel count data model of university ag-biotech patent production with a sample of 127 universities, 65 if which had received at least one ag-biotech patent between 1994 and 1999. They found strong evidence of a correlated dynamic effect in which patenting

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experience helps to produce more patents and that patent production is enhanced by the overall university propensity to patent (patenting culture effects), a strong land grant effect, and a biological science research funding effect. They did not find convincing evidence that university reliance on industry financing increases patent production (there were no industry effects present).

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As we emphasized above, the analysis of the European case began more recently than the analysis of the US situation, and the empirical evidence for Europe is not extensive. The recent review by GEUNA and NESTA, 2006, of European academic patenting concluded that the broadly defined research area of biotechnology and pharmaceuticals tends to be an area of extremely high university patenting activity across (European) countries. Second, historical developments in Italy and Germany seem to support the view that university patenting is not a new phenomenon. The authors also suggested that the rapid rise of academic patenting was driven more by the growing technological opportunities in the biomedical sciences than by policy changes affecting the universities' rights to own patents arising from publicly funded research. In the next paragraphs, we review what the empirical European literature says about university patenting and its determining factors.

SARAGOSSI and VAN POTTELSBERGHE, 2003, carried out a descriptive analysis of patenting activity in six Belgian universities. They found an increase in patents, which they attributed to two major changes: the new technological opportunities resulting from research activities related to the biotechnology sector, and an increased propensity to patent technologies developed by Belgian universities (also related to more effective technology transfer offices). BALDINI *et al.*, 2006, analysed a set of 637 patent applications filed at the Italian Patent and Trademark Office, the European Patent Office, and the US Patent and Trademark Office between 1965 and 2002, with at least one applicant belonging to the official list of higher education institutions. Their empirical results showed that, in the last 10 years, the number of Italian university patent applications, in Italy and/or abroad, rose substantially; patenting activities almost tripled in universities with an internal Intellectual Property Right regulation, after controlling for several universities' characteristics, previous patenting activity, and time trends. Each time a university creates its own patent regulation, there is a 9% increase in the likelihood that universities without any internal patent regulation will adopt one. Furthermore, consistent with previous studies on academic patenting, BALDINI *et al.*, 2006, found greater patenting activity in the north of Italy, where there is a higher level of industrial development. In a broad paper, in which the authors considered a patent as an input and an output, AZAGRA-CARO *et al.*, 2003, estimated a patent production function using data on patent applications from 43 departments of the Polytechnic University of Valencia (Spain) from 1991 to 2000. Their results showed that the aggregate R&D expenditure has a positive effect on patents, but they found decreasing returns to scale. When they used R&D split by source of funding, they found that government and industry funding has a significant and positive effect, and that the public funding is more important for patenting than private funding. The internal characteristics of departments are relevant in patent generation.

We have briefly reviewed some of the key papers on the determinants of university patents, but none of these studies focused on the regional level. To our knowledge, only AZAGRA-CARO *et al.*, 2006, discussed the analysis from a regional perspective. They built a university patent production function to identify the factors determining the generation of patents in 17 Spanish autonomous regions (NUTS-II). They used a sample of 1,479 patents (1,398 national and 81 international) over a time span of 14 years (from 1988 to 2001). As in previous research, they found a significant positive relation between the number of university patents and academic R&D in all estimations (they found that academic R&D was the only significant determinant of

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international university patents), but their elasticities were extremely high compared with previous papers applied in other contexts. The authors explained this as being the result of using different units of observation (regions instead of universities) and the inclusion of all the funds (not only public funding). Other significant variables to explain the production of national patents are control variables (trend), and an index of technological distance between university patenting and other institutions. They did not find evidence of the effects of variables such us the number of university researchers, university structure, or the joint research structure (specific economic variables reflecting demands factors from the regions were not included in this paper). This was an interesting attempt to analyse the issue at a regional scale, but as a drawback it should be noted that although they used a panel for 14 years, the data included only Spanish regions, which represent very heterogeneous spatial units, making it difficult to obtain econometrically consistent results. That is, the number of universities and the number of university patents vary significantly across Spanish regions (which probably generates spatial heterogeneity biases). As far as we are aware, empirical studies on university patenting at a macro regional scale in Europe are nonexistent.

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3. University patenting in the European regions: an overview

This section presents a description of regional university patenting activity across the European Union. In our empirical analysis, we use 4,580 European university patents (obtained from the Derwent Innovation Index) related to 202 European regions and 378 universities for the period from 1998 to 2004.[3] As regions for our analysis, we chose the territorial units from Eurostat in each country at the NUTS II level of aggregation. As is well known, a NUTS II is a territorial unit with some degree of administrative and policy authority.

In order to regionalize the university patents, we followed two steps. First, we identified all the universities for each region. In the second step, we gathered all the patents from each university situated in the same region. A patent was assigned to a university (and in consequence to a region) when the name of the university appeared in the list of applicants of the patent, so the name of the university was the criterion for detecting a university patent.[4] When more than one university appeared on the list of applicants, we assigned the patent to the first applicant. Therefore, what we are considering in this paper is a university-owned patents (those that have at least a university as one of the applicants), and not the production of a patent by an inventor (researcher/professor) from a university. The review by VERSPAGEN (2006) includes some figures for six European countries where the importance of each category of patents differs substantially among countries. As GEUNA and NESTA, 2006, reported in a recent review of the literature on university patenting in Europe, the number of university-invented patents (patents with at least one inventor from a university but where the owner of the patent is a firm) is higher than the number of patents owned by universities. However, the data in our sample are dramatically different to those reported in the paper by GEUNA and NESTA, 2006, for two reasons. First, they summarized the available evidence for five European countries only (they pointed out that there were no other data available), whereas we include all European regions. Second, the papers reviewed by GEUNA and NESTA, 2006, considered a longer time period than our paper does. In the next paragraphs, we describe the data and attempt to answer some of the research questions.

3.1 Spatial distribution of the production of technological knowledge across European regions

The regional distribution of university patent counts from 1998 to 2004 is shown in Fig. 1. Of the 202 regions, 54 have no university-owned patents; 42 regions have between one and five such

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patents; 45 have between six and 15; 35 have 16 to 50; 16 have 51 to 100; and 10 regions have more than 100 university-owned patents. On average, there are 3.2 patents per region for the whole period. University patents appear to be concentrated in the regions of the UK, with other important clusters occurring in north Europe (Belgium and Holland) and in two regions of France (Rhône-Alpes and Île de France). It is worth remarking that the 54 regions where there is no university patenting activity are scattered across the European Union.[5]

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Figure 1. Regional distribution of university patents

A summary of the main statistics from the whole sample is reported in Table 1. From this Table, it is evident that the number of university patents increased from 390 to 936 during the period under examination. The coefficient of variation and the Herfindahl index reveal no substantial changes in the spatial concentration of university patenting activities from 1998 to 2004.

Table 1. European university-owned patents (1998–2004)

A closer look at the top 10 regions with the highest number of university patents confirms that the production of university technological knowledge is highly concentrated in a few regions. As is shown in Table 2, more than 25% of all the university patents are concentrated in five regions, and 10 regions account for 40% of all university patents (but only 10.5% of the population). Two regions in the UK are the most active in university patent production, namely Inner London; and Berkshire, Buckinghamshire, and Oxfordshire. The last column of Table 3 presents the number of university patents normalized by the size of the geographical unit, expressed per number of inhabitants.

Table 2. Regions with high numbers of European university-owned patents (1998–2004)

3.2 Technological specialization vs. economic specialization in regions

University-owned patents can be analysed by looking at the distribution across industrial sectors. In order to assign a patent to an industrial sector, we applied an economic concordance table, which was recently developed by SCHMOCH *et al.*, 2003, between the four-digit of the International Patent Classification (IPC) codes and the 44 industrial sectors. Using this equivalence table, we converted the original IPC data (at the four-digit level) to the Classification of Economic Activities in the European Community (NACE) at the two-digit level based on the industrial sector where the patent originated. To avoid duplication, when a patent included more than one IPC code, we considered only the primary IPC category.

By applying the concordance table to the 4,580 patents, we obtained an initial picture of the sectoral distribution of university patenting (see Table 3, which shows the five most dynamic sectors for 1998 to 2004). As shown in this table, there is a high degree of concentration in a few activities, as five industrial sectors account for 69.5% of all patents. The most active sector was patents related to pharmaceuticals, which accounted for 39.1% of all university patents. This sectoral distribution is similar to that reported by GEUNA and NESTA, 2006, in their review of papers on university patenting in Europe. The last column of Table 3 presents the most dynamic regions in each sector; note that Inner London is at the top in three of the five sectors.

Table 3. Sectors with the highest number of university-owned patents (1998-2004)

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In addition to this previous general view, Table 4 shows the specialization in the five most dynamic sectors of the 20 regions with the highest number of university patents. As a measure of sectoral specialization, we use the index of Revealed Technological Advantage (RTA), which provides information on the specialization of each region compared to the whole set of regions. The index of technological specialization is calculated as RTA = $(P_{ij}/ \Sigma P_j)/ (\Sigma P_i/ \Sigma P)$, where Pij is the number of university patents in sector i of region j; Pj is the number of university patents in region j; Pi is the number of patents in sector i across all regions; and P is the total number of university patents for all the regions. The index is greater than one when the region has a comparative advantage in that sector and is less than one when it has a disadvantage. For instance, Comunidad Valenciana (ES) and Région Wallonne (BE) are the two regions with the highest RTA in sector 10 Basic chemical; Utrecht (NL) and Tübingen (DE) have the highest RTA in Pharmaceuticals, etc.

Table 4. Technological specialization of the 20 regions with the highest numbers of university patents

In order to identify to what extent the technological specialization of the European regions is associated with their productive specialization pattern, we used an index based on sectoral employment, which is similar to productive specialization, for each region. Once both indexes were calculated (the industrial specialization and the above technological specialization index for all the sectors in which there was at least one patent), the correlation between them was obtained (Table 4, last column). This result shows that a high intraregional correlation is found in some regions (intraregional correlation)—such as Berkshire, Buckinghamshire, and Oxfordshire (0.812), and Derbyshire and Nottinghamshire (0.617) in the UK, or Tübingen from DE (0.910). However, there are also some regions with no relation or with a negative correlation. However, if we calculate the interregional correlations in the main sectors, they confirm that, on average, the

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relation between technological specialization and industrial specialization is non-existent: the coefficients are 0.018 in the Basic chemical and Pharmaceuticals sectors (calculated with 130 observations); –0.085 in the Office machinery and computers sector (with 64 observations); and 0.025 in the Medical equipment and Measuring instruments sectors (with 112 observations).

We put forward two hypotheses to explain this lack of relation between industrial specialization in regions and technological university knowledge specialization within and across some regions. The first hypothesis is that a situation may exist in which the universities are producing technological knowledge that does not cover all of the industrial specializations in the regions where they are situated, but instead they are attending to specific demands for high technology from their region or another region. The second hypothesis involves a worse situation: universities are producing technological knowledge that has nothing to do with the industrial structure of the regions because they are focusing upon academic objectives only (such as increasing academic publications). This is an important unresolved issue that requires more research.

4. Empirical framework

This section aims to establish an econometric framework to test the importance of the inputs and the regional demand factors in the process of generating new university technological knowledge, measured by patent counts. In particular, we attempt to test how university R&D funding (the main input) influences the university patent output, and at the same time to determine the potential role of private demand in regions in encouraging the creation of new technological knowledge in universities.

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4.1 The model

In order to study the relationship between outcomes measured by patent counts and R&D university funding, and other determining characteristics of the regions, we regress patents measured on funding and regional characteristics using regional level data as follows:

KPi = f(Ri,CHi, ui),

where KP is the technological new knowledge produced in universities in a region i, and R is the amount of university regional funding. R is produced as a lagged input because, as is well known, it takes time before R&D expenditure yields an output in the form of a patent. In addition, we consider a set of variables that reflect the industrial characteristics of the environment and that can affect the production of technological knowledge by a university. The acceptance of an interactive model of innovation assumes that the knowledge flows are bidirectional between the academic and industrial sectors. The existence of informal contacts between academic scientists and company researchers can generate mutual benefits for both that could have a positive impact on the universities' portfolio of patents. These factors are captured by CH, a vector of variables that picks up the potential demand for university technology in the region i. The term u represents unobservable regional differences. Note that this standard departure model is a "knowledge production function" (GRILICHES, 1979). Essentially, the model involves a neoclassical production function where knowledge is measured by means of a proxy variable (e.g., patents) and the inputs incorporate university R&D expenses, together with other spatial variables. As we pointed out above, a similar theoretical base was used by AZAGRA-CARO *et al.*, 2006; COUPÉ, 2003; FOLTZ *et al.*, 2000; FOLTZ *et al.*, 2003; PAYNE and SIOW, 2003. However, our framework is substantially different because the models in these papers included only the supply-side factors (funding and

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university characteristics), whereas we also introduce potential regional demand-side effects as a factor that may encourage or hinder the production of university patents.

4.2 Variables and econometric specification

Our dependent variable is the count of university patents, used as a measure of the production of new university technological knowledge in regions.

Our explanatory variables are as follows.

- University funds. We include R&D university regional funding measured as millions of Purchasing Power Standards (PPS) in 1995 prices (R variable). We lag the funding measure in separate specifications by three years (following PAYNE and SIOW, 2003) and two years (FOLTZ *et al.*, 2003) in order to prevent endogeneity. Furthermore, this allows us to compare the results.

- Potential demand for university technology. As reviewed above, some empirical papers without a specific focus on regions have stressed the importance of the demand side in encouraging university patenting activities. In particular, SARAGOSSI and VAN POTTELSBERGHE (2003) highlighted the new technological opportunities resulting from research activities related to the biotechnology sector, and BALDINI *et al.* (2006) found greater patenting activity in the north of Italy, where there is a higher level of industrial development. From a regional viewpoint, the recent paper by KOO (2007) tackled a related topic: the endogenous relationship between spillovers and the role of regional and industrial attributes (the demand side). This paper provided substantial evidence that agglomeration, industry structure, small establishment, and local competition play important roles in the localization of technology spillovers. On the other hand, it

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should be borne in mind that there are serious doubts as to whether the potential demand for university knowledge remains local for several sectors. In particular, this is the case for some centres or universities of "excellence". For instance, COOKE'S (2004, 2005) comprehensive research on bioscience megacentres reported some instances where academic and public laboratory scientists evolved "dynamic capabilities" that attracted entrepreneurs from different locations to engage in tacit knowledge exchange. However, once firms are located near universities, those companies will get early access to local inventions (for example, university patents) generating what COOKE (2005) referred to as "precipitatory knowledge".

Our main interest including this variable is to question whether regional demand is relevant in promoting university patenting. In order to capture the regional demand-side factors that can determine the production of university patents in universities, we include the variable gross industrial domestic product (GIP) in the models as a proxy of the industrial capacity of the region, and, consequently, of the regional potential to demand university technology. This variable also accounts for the (industrial) size of regions, preventing spatial heterogeneity bias.

- Spatial fixed effects. We consider national dummies in order to capture the different political and institutional contexts that can encourage university patenting activity. Particularly relevant in this respect is the legal situation regarding university patents in Europe. This issue is important for two reasons. On the one hand, the legal context is an institutional mechanism that enables (or hinders) the development of university knowledge production. It is important to note in this regard that each European country has its own legal system of patents (see OECD, 2003, for details). Therefore, the legal situation is an element of the national innovation system that has to be taken into account as a cause of differences in the production of university knowledge among regions in different countries. BALDINI *et al.* (2006) reported some studies showing that patent policies are

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among the determinants of intercountry and interorganizational differences. On the other hand, in our empirical analysis, we consider a database of "university own patents". This is one of the categories of patents that involve university knowledge, as we mentioned earlier, with the other type including patents applied by inventors employed by universities. The importance of one or the other type of patent differs between countries depending on the patent law of each (see VERSPAGEN, 2006).

We also consider regional spatial effects, but regional dummies are impossible to include because of a lack of degrees of freedom, so we consider only a single regional variable that takes a value of one if the region i is an Objective 1 region (producing less than 75% of the average GDP per capita of the European Union) and 0 otherwise. Objective 1 regions are those that are lagging in terms of their development, and they normally have a weak regional system of innovation and little capacity to demand technology from a university.

- Temporal effects. Finally, we include dummy variables for years to control for fixed temporal effects.

Because we are dealing with a count variable as the dependent variable, the nature of the data suggests the formulation and estimation of a counting (Poisson or negative binomial) model to detect the intensity of the technological knowledge creation. As in most previous studies, our baseline specification assumed that the dependent variable followed a Poisson distribution, where the set of regressors is given by X = (R, GIP, OBJ1, YEAR DUMMIES, SPATIAL DUMMIES).

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The standard procedure for computing the estimators is the Newton–Raphson iterative method. Convergence is ensured because the logarithmic likelihood function is globally concave. However, one restriction of the Poisson model is that it assumes that the mean and variance of the dependent variable are equal, so this framework breaks down when the data are overdispersed; that is, when the variance of the dependent variable is greater than the mean, a requirement that cannot always be met in practice. If the data show overdispersion, the standard errors of the Poisson model will be biased toward the low end, giving spurious high values for the t-statistics (CAMERON and TRIVEDI, 1986). Because equality of the mean and variance does not hold in the data, we consider a number of different models that do permit overdispersion. The most common formulation for taking overdispersion into account is the negative binomial model (NB2, in the terminology of CAMERON and TRIVEDI, 1986, which assumes that the variance is a quadratic function of the mean (the approach for the density function, logarithmic likelihood function, first-order conditions, etc., is similar to the above, and is discussed in detail in CAMERON and TRIVEDI, 1998).

4.3 Data

Our sample contains 4,580 European university patents from the European Patent Office (obtained from the Derwent Citation Index) related to 202 European regions and 378 universities in the period from 1998 to 2004 (this sample is the same as described above -in Section 3-, where we explained how the data were obtained). Unfortunately, however, we have no data for the explanatory variables for all regions (with the exception of the dummy “Obj1”). University R&D funds and regional industrial domestic product (obtained from EUROSTAT) are only available for some regions and years. Another problem is that the panel is unbalanced (the regions in one year

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are not exactly the same as those reported in the following years). Table 5 contains the data used in our models.

Table 5. Number of regions with data available for the explanatory variables

4.4 Results

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Our baseline specification assumed that the dependent variable followed a Poisson distribution, but the presence of overdispersion led us to consider negative binomial models as well. As is shown in Table 6, four models have been estimated with all the variables described above, including those to control for spatial and temporal fixed effects. For the first group (Models I and II), we have lagged the inputs by three years, and for the second group (Models III and IV), we have lagged the inputs by two years. Models I and III include Poisson specifications with robust standard errors to avoid spurious high values for the t-statistics. Models II and IV include negative binomial specifications.

The results in all the models are quite similar. Given that the university funds are expressed in logarithmic form, the coefficients for the R variable provide estimates of elasticities. As shown in Table 6, these elasticities for university funds present coefficients of around one (0.93–1.04), indicating constant returns to scale. This result is in line with the first part of the paper by COUPÉ, 2003, who found constant returns to scale in his analysis of university patents (or decreasing returns after controlling for fixed effects), although he used universities as a unit of observation in his papers. PAYNE and SIOW, 2003, also obtained decreasing returns, but they considered only a part of university funding. Finally, our results contrast strongly with those obtained by AZAGRA-CARO *et al.*, 2006, whose paper focused on Spanish regions and found extremely high elasticities, which were attributed to a high level of aggregation for these spatial units.

We did not find evidence of the possible effects that the industrial potential may have on the production of university technological knowledge. The variable GIP is not relevant in all the specifications. This is an important issue because it indicates that the production of university technological knowledge does not appear to be supported by potential industrial demand in regions, a surprising result that requires further investigation. On the one hand, it is possible that universities are responding to global demands coming from outside the regional borders and, as a consequence, the role of the economic regional demand is limited in encouraging the production of university patenting. However, on the other hand, GIP may not be the best variable to represent regional technological demand, and future research may need to consider better proxies.

The spatial fixed effects captured by the country dummies are all significant and with wide differences between them (note in Table 6 that the base category is the UK). These results emphasize the importance of the political and institutional context in producing differences in the production of university technological knowledge in regions. Finally, the dummy variable Obj1 is not significant, but, as we comment below, this is because its effect overlaps with that of the country dummies.

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Although the results of the models are similar, it is necessary to determine which one is better. In order to compare the Poisson models with the NB models, two overdispersion tests were applied: a t-test on the overdispersion parameter alpha, and an LR test comparing the log likelihood of the Poisson models against the log likelihood of the NB models. Both tests select the NB models over the Poisson models (see the statistics in Table 6). On the other hand, there are no substantial differences between the models with three or two years of lags, probably because in some regions two years are needed to translate resources into patents, but in other regions an extra year is required. Note, however, that the models with two-year lags present a slightly better fit.

Table 6. Effects of regional university R&D funds and industrial potential of regions on university patents

The final issue is to determine how robust our results are. We have run other regressions to address this issue, as follows.

First, we carried out a sensitivity analysis with some alternative specifications, dropping some variables from the base models and estimating new models with some variables omitted. The results can be summarized as follows. Elasticities of around one (0.99–1.10) are obtained in all the models if we consider only R as the explanatory variable (always with two or three lags). Taking out fixed temporal and spatial effects from the models does not greatly change the original elasticities; however, more variability appears, as indicated by coefficients with values between 0.87 and 1.11). The coefficient for GIP is not significant in most of the specifications. The variable OBJ1 becomes significant when we remove the country dummies from the models, suggesting an overlap effect, but the fit is considerably worse.

Second, we obtained intragroup estimations (obtained not by pooling the data for all the available years, but by taking a sample of regions for every year) with two and three lags for the explanatory variables, and ran both Poisson and negative binomial models. The results for these models were not substantially different from the previous models. Again, elasticities were around one for R, coefficients for GIP were not significant, and there were considerable spatial differences among countries. Table 7 summarizes all the results.

Table 7. Summary of results

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Conclusions

This paper was a first attempt to understand the distribution of technological knowledge generated in universities, measured by patent counts, at a regional level in Europe. Our research design involved two parts. First, a descriptive analysis was carried out to analyse the spatial distribution of university patents. Our main findings from this part of the analysis were a strong regional and sectoral concentration of patents, and no average relation between technological specialization and industrial specialization. In the second part of the research, an econometric analysis was undertaken to identify which factors determine the production of university patents. However, determining the causal links between possible explanatory causes and university patenting is a difficult task, because regional heterogeneity, endogeneity, correlations between inputs, and spatial/time fixed effects have to be taken into account. Controlling for all these difficulties in our models, we found that variations in regional R&D funding do affect patenting activities in regions, with elasticities showing constant returns to scale. Furthermore, all the specifications showed significant country dummies, revealing the importance of the institutional context in producing university patents in regions.

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Our empirical analysis raises some questions that are relevant to the debate regarding regional innovation policies at different levels. According to our data, universities in regions play an important role in generating technological knowledge (patents) with potential application to the market. Promoting this role should be a priority in order to foster entrepreneurial universities that strengthen regional innovation systems. European institutions and national governments should have a strong interest in promoting such a role for three reasons. First, there is a large skewed spatial concentration of patents (10 regions have more than 100 university patents, but more than

50 regions have no university patents); amending this imbalance is recommended in order to avoid wider regional disparities in the future. Second, money is important; there is a direct relation between the amount of university R&D resources and university performance in terms of numbers of university patents (with constant returns to scale). Therefore, financial grants are essential to promote entrepreneurial universities. Another implication of this finding is that investing extra money in university R&D in large regions is as effective in stimulating the production of university patenting as is investing extra money in small regions. Third, the institutional context is relevant to encouraging the production of university patenting. In particular, each country has its own legal framework that generates differences in university patent productions. It may be necessary to consider a more (supranational) homogeneous legal system for industrial property in universities.

Finally, we found an intraregional correlation between technological specialization in universities and regional economic specialization only in a few regions. This is probably a result of the fact that universities in many regions are involved in projects unrelated to the technological necessities of their environment. Therefore, there are some potential steps for the regional governments with competencies in R&D to consider, such as reinforcing (or establishing) the mechanisms to encourage interactions with local firms, and promoting the kind of university technological knowledge that can support industries in the same regions where the universities are located.

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NOTES

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[1] Note that other important channels of interaction such us employment of graduates by firms or training of firm members have nothing to do with a patent.

[2] For instance, in the US, the state governments and regions have promulgated specific policies and programmes to exploit research universities as drivers of innovation and high technology-based economic growth. Universities and their research spending are essential assets and the foundation for high-tech regional growth initiatives (SONKA and CHICOINE, 2004).

[3] It should be noted that the number of European university patents is considerably lower than the number of national ones. The reason for gathering only European patents in our sample is to avoid the national distortions arising from the different patent application requirements in different countries. Furthermore, the higher costs for a national patent compared to a European patent suggest that we are dealing with valuable technological knowledge with real potential applications.

[4] We have considered that a patent belongs to a university when the university's name appears in the list of applicants. To avoid problems with the university name, we considered that institutions included in the European Indicators, Cyberspace, and the Science–Technology-Economy – System (EICSTES) Project and in the Worldwide Web of Universities (www.univ.cc, web site with links to 7,884 universities in 190 countries).

[5] As we pointed out in the description of the data, note that we are considering university-owned patents in this paper. Therefore, this spatial distribution does not necessarily coincide with other criteria (for example, it excludes patents that are invented by academic researchers but where the university does not appear on the patent's applicant list).

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Table 1. European university-owned patents 1998–2004

	1998	1999	2000	2001	2002	2003	2004	1998–04
No. of Patents	390	402	606	639	710	897	936	4,580
Mean	1.9	1.9	3.0	3.1	3.5	4.4	4.6	3.2
Maximum	37	42	74	57	74	79	47	410
Minimum	0	0	0	0	0	0	0	0
Std.Dev.	4.3	4.6	7.7	6.8	8.0	9.2	8.1	7.2
Coeff. of Variation (*)	2.2	2.3	2.5	2.1	2.2	2.0	1.7	2.2
Herfindahl (**)	0.030	0.032	0.038	0.028	0.031	0.026	0.020	0.026
Obs.	202	202	202	202	202	202	202	202

(*) C.V. = Std.Dev/Mean

(**) The Herfindahl index of geographical concentration shows how concentrated the production of university technological knowledge is across regions (the coefficient takes a value of one for maximum concentration, that is, if all patents were assigned to one region, and 1/n for an equal distribution, where n = 202 regions).

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Table 2. Regions with high numbers of European university-owned patents (1998–2004)

Region	NUT II	Patents	%	% Concentration	Patents/hab(*)
Inner London	UKI1	410	8.95	8.95	142.99
Berkshire, Buckinghamshire, and Oxfordshire	UKJ1	257	5.61	14.56	122.41
Vlaams Gewest	BE2	220	4.80	19.37	36.69
Zuid-Holland	NL33	188	4.10	23.47	54.65
Île de France	FR10	144	3.14	26.62	12.83
Eastern Scotland	UKM2	132	2.88	29.50	67.06
South-western Scotland	UKM3	131	2.86	32.36	55.98
East Anglia	UKH1	127	2.77	35.13	57.96
Rhône-Alpes	FR71	112	2.45	37.58	19.19
Gloucestershire, Wiltshire, and North Somerset	UKK1	110	2.40	39.98	50.67
Others		2,749	60.02	100.00	8.03
All regions		4,580	100.00		11.97

(*) Number of university patents per million inhabitants
Source: Derwent Innovation Index

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Table 3. Sectors with the highest number of university-owned patents (1998–2004)

Field no.	Description	Patents	%	% Concentration	Regions with the highest number of patents in each sector
13	Pharmaceuticals	1,793	39.15	39.15	- Inner London (UK) (11.2%) - Berkshire, Buckinghamshire, and Oxfordshire (UK) (6.9%) - Vlaams Gewest (BE) (5.1%) - Zuid-Holland (NL) (4.6%) - Île de France (FR) (3.8%)
38	Measuring instruments	430	9.39	48.54	- Inner London (UK) (10.2%) - Berkshire, Buckinghamshire, and Oxfordshire (UK) (5.6%) - Vlaams Gewest (BE) (5.6%) - East Anglia (UK) (4.2%) - South-western Scotland (UK) (4.0%)
10	Basic chemical	388	8.47	57.01	- Comunidad Valenciana (ES) (10.3%) - Berkshire, Buckinghamshire, and Oxfordshire (UK) (6.4%) - Eastern Scotland (UK) (4.9%) - Region Wallone (BE) (3.6%) - Northumberland and Tyne and Wear (UK) (3.6%)
37	Medical equipment	374	8.17	65.17	- Inner London (UK) (13.6%) - Rhône-Alpes (FR) (5.1%) - Tübingen (DE) (3.7%) - Île de France (FR) (3.7%) - Zuid-Holland (NL) (3.7%)
28	Office machinery and computers	200	4.37	69.54	- Berkshire, Buckinghamshire, and Oxfordshire (UK) (9.5%) - Inner London (UK) (7.0%) - Greater Manchester (UK) (6.5%) - South-western Scotland (UK) (5.5%) - Île de France (FR) (5.0%)
Others		1,395	30.46	100	
All patents		4,580	100		

Source: Derwent Innovation Index

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Table 4. Technological specialization of the 20 regions with the highest numbers of university patents

Regions	No. of Patents	% Pat High tech	Sectors (*)					Intraregional Correlation (***)
			10	13	28	37	38	
Inner London (UK)	410	0.94	0.35	1.25	0.78	1.52	1.14	0.061
Berkshire, Buckinghamshire, and Oxfordshire (UK)	257	0.96	1.15	1.22	1.69	0.62	0.99	0.812
Vlaams Gewest (BE)	220	0.89	0.54	1.07	0.62	0.61	1.16	0.498
Zuid-Holland (NL)	188	0.95	0.82	1.11	0.61	0.91	0.91	0.123
Île de France (FR)	144	0.94	0.25	1.21	1.59	1.19	0.74	–0.228
Eastern Scotland (UK)	132	0.95	1.70	0.87	0.35	1.11	1.29	–0.397
South-western Scotland (UK)	131	0.94	0.27	0.88	1.92	0.93	1.38	0.056
East Anglia (UK)	127	0.94	1.02	0.95	1.26	0.48	1.51	–0.472
Rhône-Alpes (FR)	112	0.96	1.37	0.50	1.64	2.08	1.14	–0.140
Gloucestershire, Wiltshire, and North Somerset (UK)	110	0.93	0.00	1.07	1.04	0.89	1.07	–0.277
Greater Manchester (UK)	99	0.97	1.19	0.88	3.01	1.24	1.61	–0.139
Hampshire and Isle of Wight (UK)	96	0.86	0.12	0.43	1.67	0.77	0.55	–0.362
Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest (BE)	85	0.95	0.56	1.11	1.62	0.29	0.38	0.142
South Yorkshire (UK)	76	0.95	1.09	1.31	0.90	0.97	0.28	0.269
Southern and Eastern (IE)	75	0.97	0.79	1.19	1.83	0.33	0.85	0.449
Utrecht (NL)	73	0.97	0.81	1.68	0.00	1.17	0.29	0.589
Derbyshire and Nottinghamshire (UK)	71	0.94	0.33	1.04	0.32	1.90	1.20	0.617
Tübingen (DE)	70	0.99	0.67	1.35	0.00	2.45	1.83	0.910
Comunidad Valenciana (ES)	65	0.88	7.26	0.12	0.00	0.75	0.33	–0.304
Région Wallonne (BE)	62	0.94	2.67	0.91	0.74	0.40	0.86	0.198

10 Basic chemical
13 Pharmaceuticals
28 Office machinery and computers
37 Medical equipment
38 Measuring instruments

(*) Technological specialization (index of Revealed Technological Advantage).
(**) The Herfindahl Concentration Index for 44 industrial sectors (maximum concentration = 1; minimum concentration = 0.022)
(***) Intraregional correlation: Spearman Correlation Coefficient between technological specialization (university patents) and economic specialization (employment). This coefficient was calculated with all the sectors and not only with those presented in this table.

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Table 5. No. of regions with data available for the explanatory variables

YEAR	Variables			Obs. three lags (1)	Variables			Obs. two lags (2)
	R&D (t-3)	GIP (t-3)	Both		R&D (t-2)	GIP (t-2)	Both	
1998	(*)	-	0	0	(*)	0	0	0
1999	(*)	-	0	0	121	163	90	90
2000	121	163	90	90	114	163	81	81
2001	114	163	81	81	127	163	92	92
2002	127	163	92	92	150	165	117	117
2003	150	165	117	117	154	165	119	119
2004	154	165	119	119	115	164	79	79
Unbalanced panel				499				578

(*) Data on lagged university R&D or GIP for these years are not available or include too much missing data.

(1) Regions (observations) included in the models with three lags in the explanatory variables.
(2) Regions (observations) included in the models with two lags in the explanatory variables.

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Table 6. Effects of regional university R&D funds and industrial potential of regions on university patents

Variable	THREE LAGS FOR R and GIP						TWO LAGS FOR R and GIP					
	MODEL I Poisson Count (1)			MODEL II Negative Binomial Count			MODEL III Poisson Count (1)			MODEL IV Negative Binomial Count		
	Coeff.		Std. Err.	Coeff.		Std. Err.	Coeff.		Std. Err.	Coeff.		Std. Err.
C	–3.872	*	0.853	–4.380	*	0.717	–4.258	*	0.898	–4.682	*	0.698
LOG(R)	0.933	*	0.072	1.031	*	0.078	0.955	*	0.069	1.043	*	0.076
LOG(GIP)	0.122		0.121	0.125		0.100	0.142		0.124	0.142		0.095
Year04	0.528	*	0.192	0.605	*	0.161	0.978	*	0.230	0.987	*	0.183
Year03	0.598	*	0.182	0.637	*	0.158	0.735	*	0.213	0.786	*	0.184
Year02	0.206		0.199	0.306	*	0.171	0.566	*	0.209	0.595	*	0.180
Year01	0.051		0.208	0.152		0.171	0.530	*	0.219	0.559	*	0.190
Year00							0.263		0.247	0.208		0.192
Small countries (2)	–0.547	*	0.170	–0.781	*	0.186	–0.786	*	0.151	–0.901	*	0.182
DE	–1.092	*	0.173	–1.149	*	0.198	–1.493	*	0.163	–1.576	*	0.206
GR	–4.192	*	1.050	–4.110	*	1.039	–4.301	*	1.021	–4.223	*	1.045
ES	–1.143	*	0.162	–1.165	*	0.173	–1.472	*	0.155	–1.476	*	0.177
FR	–1.152	*	0.164	–1.246	*	0.145	–1.509	*	0.148	–1.522	*	0.155
IT	–1.860	*	0.177	–2.019	*	0.180	–2.311	*	0.169	–2.393	*	0.201
PT	–2.389	*	0.367	–2.334	*	0.464	–2.883	*	0.406	–2.820	*	0.460
FI	–2.748	*	0.571	–2.813	*	0.476	–2.948	*	0.487	–2.895	*	0.414
OBJ1	0.071		0.140	0.013		0.144	0.099		0.127	0.062		0.142
Alpha				–0.838	*	0.144				–0.697	*	0.131
Log likelihood	-1010.11			–863.69			–1147.83			–958.30		
LR statistic (15 df)	3286.32	*		3579.16			3898.68	*		4277.73	*	
Pseudo-R2	0.62			0.67			0.63			0.69		
LR=2($\ln L_{NB}$-$\ln L_{P}$)				292.84	*					379.06	*	

Notes:

(1) Eicker–White standard errors.

(2) This variable takes a value of one for some small countries where data were available only for one or two regions, and zero otherwise. Other European countries do not appear in the table because of a lack of R&D data. The base category is the UK.

The symbol * denotes significant coefficients with a p value of less than 0.05.

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Table 7. Summary of results

MAIN SPECIFICATIONS	VARIABLES	MAIN RESULTS
MODELS I to IV (From Table 6)	Log (R)	- Significant coefficients of around one for all the models (0.93–1.04), indicating constant returns to scale.
	Log (GIP)	- No evidence of the possible effects that the industrial potential may have on the production of university technological knowledge.
	Year dummies	- Significant coefficients for several years. Evidence of temporal effects.
	Country dummies	- Significant coefficients showing the importance of the political and institutional context in countries to generate differences in patent production.
	OBJ1	- Coefficient no significant for this variable, but note that this effect overlaps with that of the country dummies.
ROBUTNESS		
SENSIVITY ANALISIS I (Poisson and NB models including only Log (R) as explanatory with two and three lag).	Log (R)	- Significant coefficients in all the specifications. Elasticities of around one (0.99–1.10)
SENSIVITY ANALISIS II (Poisson and NB models including Log (R) and Log (GIP) as explanatory variables with two and three lag).	Log (R)	- Significant coefficients for Log (R). Elasticities with more variability (between 0.87 and 1.11). - No significant coefficients for Log (GIP)
	Log (GIP)	
INTRAGROUP ESTIMATIONS (Poisson and NB models for every year with data available).	Log (R)	- Elasticities were around one for R.
	Log (GIP)	- No significant coefficients for most of the models.
	Country dummies	- Significant coefficients for country dummies. Considerable spatial differences among countries

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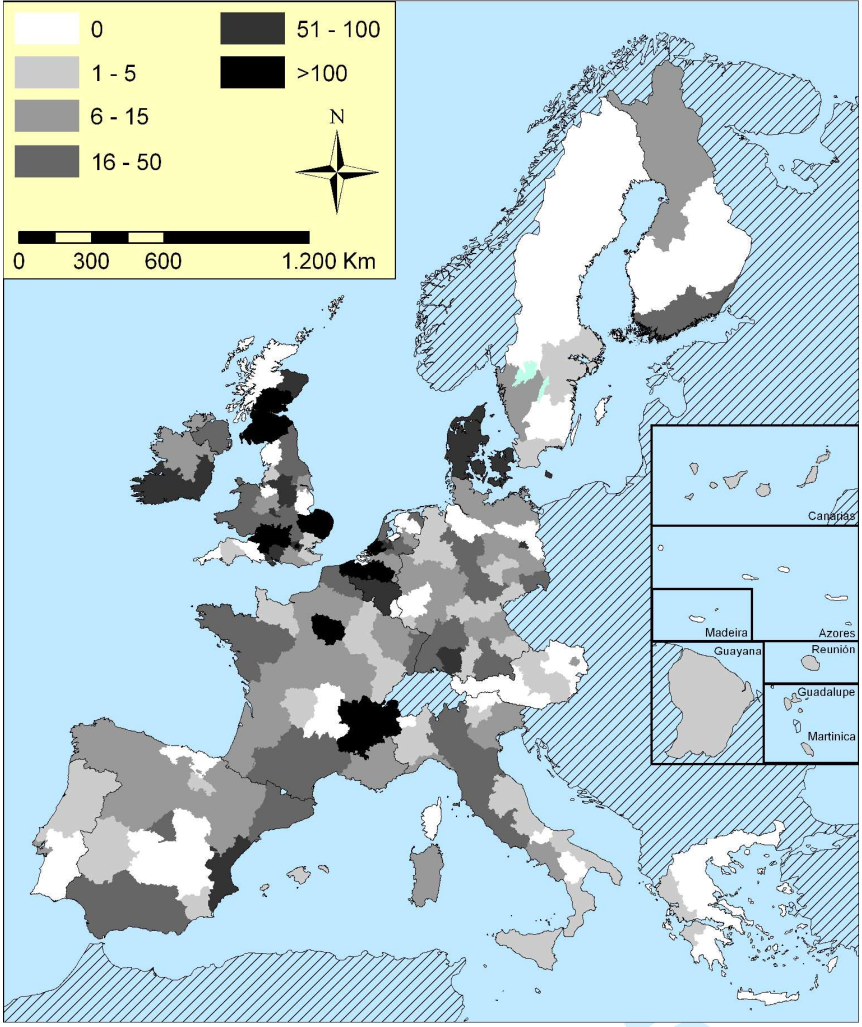
Figure 1. Regional distribution of university patents



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