THE EFFECTS OF REGIONAL SCIENTIFIC OPPORTUNITIES IN SCIENCE-TECHNOLOGY FLOWS: EVIDENCE FROM SCIENTIFIC LITERATURE CITED IN FIRMS' PATENT DATA.

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Abstract:

The objective of this study is to advance, from a quantitative point of view, in the knowledge of the science-technology flows from a regional perspective. The methodology utilised in this study is based on the scientific citations in patent documents (NPC), and has previously only been applied in national contexts. After describing the spatial and sectorial patterns, we propose to identify the explanatory factors by modelling the citations in patent documents (taking this variable as a proxy for the science-technology flows) in function of a set of three blocks of explanatory factors: businesses (microeconomic variables), industries (sectorial variables) and spatial contexts (variables of location and of the scientific environment). The model is of the microeconomic type and the most appropriate formulation, given the nature of the endogenous variable, is that of the counted data type. The statistical data originate from a comprehensive review of the 1,643 patents applied for by 1,129 companies, and published during the years 1998 to 2001, both inclusive. The basic source of data is the domestic patent documents themselves, published by the Spanish Office of Patents and Trade Marks. This information has been tabulated to obtain regional indicators of science-technology flows and the variables for inclusion in the model. The statistical treatment of the primary information and the operation of the model provide us with objective data that may serve as an additional point of reference for reflecting on the incidence on the regional productive system of specific measures taken under regional scientific policies.

Key words: Science-technology flows, regional spillovers, patent data.

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1. Introduction

It is well known that many regional governments in Eurpe enjoy considerable degrees of autonomy and have set about drawing up plans for R&D; in many of these plans, the financing of scientific work in regional universities constitutes the fundamental part of the planned actions. One of the key arguments for allocating huge quantities of resources from regional budgets to local universities has been a general belief that the strengthening of scientific activity translates to industrial growth in the form of more and better product and process innovations. The principal objective of this work is to determine if the regional expenditures allocated to building a strong scientific capability are related to a greater utilisation of the results of academic scientific research on the part of those companies that generate patentable technology. To draw the regional map of science-technology flows, we assume that the scientific citations in the patent documents filed by the patent applicant are an adequate indicator to represent the use of scientific knowledge by the private sector of industry.[1]. The picture we present in this study provides new empirical evidence in respect of the complex science-technology relationships that can be utilised as one more element in judging the value of future regional action in R&D planning.

This study contributes various novel elements. In the first place, no previous empirical investigations have been made, for the case of Spain, studying how the scientific community influences the transfer of scientific knowledge to the industrial sector, its sectorial characteristics and its regional distribution. In the second place, a framework is suggested for identifying, from a microeconomic viewpoint, the lines of corporate behaviour in the use of scientific knowledge, and their explanatory causes.

The article is organised in the following way. In continuation, we describe the basic aspects of the methodology and details of the variables that we employ. Then we

[1]In the 1990's, studies such as those of Van Vianen et. al., (1990), Grupp and Schmoch (1992), Narin and Olivastro (1992, 1998), Noyons et al. (1994), Narin et al. (1995, 1997), Meyer-Krahmer and Schmoch (1998), among others, have demonstrated that the mean number of scientific references cited in patents is an appropriate indicator for describing science-technology relationships. Recently various analyses with various levels of aggregation have been carried out, that are enabling us to make progress in interpreting the role played by scientific citations in patent documents for the quantification of science-technology relationships (Meyer, 2000a, 2000b, 2000c, 2002; McMillan et al., 2000; Tijssen, 2000, 2001, 2002; Verbeek et al., 2002). In the section on methodology, we state the limitations of the procedure.

formulate various models model for identifying the possible effects of the resources dedicated to university research, on the use of scientific knowledge by the industrial sector. Thirdly, we give details of the data utilised and the descriptive analysis of this data. Fourthly, we present the results estimated by the models specified. Lastly, we summarise and discuss the implications of the principal results

2. Methodology

The empirical tradition for the analysis of the externalities or spillover effects of university research on regional innovation follows the formulation of the knowledge production function initiated with the work of Griliches (1979), and modified by Jaffe (1989), Feldman (1994) and Audretsch and Feldman (1996) to include the spatial dimension. In essence, this involves a neo-classical production function where knowledge is measured by means of a proxy variable (e.g. number of inventions, innovations, etc.) and the inputs incorporate, in addition to the classic factors, university research, together with other spatial variables. In this study, we adopt a different approach, since our intention is not to analyse the effects on the regional innovative capacity, but rather the effects on the use made by companies of the scientific knowledge generated in the universities.

The basic reason for studying the use of scientific knowledge from a microeconomic point of view stems from the assumption that knowledge in general, and the scientific kind in particular, should contribute to improving and making more efficient the inventive efforts of companies and the quality of their innovations; as a consequence, this knowledge will reduce companies' costs and increase the market value of these companies (see Blundell et al., 1999). The empirical testing of the relationship between stock of knowledge (scientific and technological) and market value of companies has been performed in the framework provided by a specification suggested by Griliches (1981) and recently utilised by Hall et al. (2001) and Bloom and Van Reenen (2000). The factors utilised to explain the market value are the stock of knowledge in general, together with other regressors that reflect the internal structure of the company. Knowledge is, however, a difficult input to quantify; usually it has been measured in microeconomic models by indicators that aggregate scientific and technological knowledge (R&D expenditure, numbers of scientists and engineers employed, patents weighted by quality level, etc.). In this context, our intention is to contribute to the explanation of what are the factors that condition or determine one of the resources -the use of scientific knowledge- of the companies that generate technology. To represent this phenomenon adequately, we suggest a function of utilisation of scientific knowledge; this is a variable that will depend both on a company's needs and/or possibilities for adopting this knowledge, and on the opportunities that the company's business environment offers for its transmission. In other words:

$$SK_i = f(C_i, T_i)$$

Where SK represents corporate use of scientific knowledge in the development of a specific technology for firm i; this scientific knowledge use is explained by:

- A vector C of variables, expressing the general need for, and the ability to adopt and absorb scientific knowledge for firm i.
- A vector T of variables, denoting the opportunities available for the transfer of scientific knowledge for firm i.

To quantify the variable SK in this work, we utilise the scientific citations in patent documents as valid indicators reflecting the use made of scientific knowledge in a particular industry. We assume, as has been argued in other recent studies (Meyer, 2000a, 2000b, 2000c, 2002; McMillan et al., 2000; Tijssen, 2000, 2001, 2002; Verbeek et al., 2002), that the scientific citations in patent documents (NPC) are a proxy variable to represent a particular portion of scientific knowledge useful in the development of patented technological knowledge. The inventions patented generally incorporate public and private knowledge in different proportions, and this materialises in references to or citations of other patents and scientific literature. In patent documents, as occurs in scientific articles, it is usual to provide references or citations, the objective of which is to describe the antecedents or "state of the art" prior to the invention. The antecedents or state of the art include, not only other patents that have been utilised as support for the invention, but also bibliographical references to scientific literature and technical publications (NPC). These citations provide some indications of the potential contribution of the published research to the inventions patented. Assuming the limitation, the NPC citations are the dependent variable that we shall attempt to explain through the following regressors that, as mentioned earlier, are divided into two groups:

Opportunities for the transmission of scientific knowledge presented by the environment

Opportunities for the transfer of scientific knowledge may be defined by the concept of academic knowledge spillovers, namely, formal and informal movements of new ideas based on scientific principles, concepts or technical procedures, from their origins in university research work through to their application in the private sector (Jaffe, 1989). In principle, it would follow that a company located in a geographical area with a high concentration of university establishments, is more likely to take earlier advantage of the scientific knowledge which is available at close hand than companies based elsewhere, bearing in mind that geographical proximity reduces the costs of face-to-face communication (Fritsch and Schwirten, 1999; Goe et al., 2000). A number of studies with aggregate data support this hypothesis, although their results are inconclusive (Anselin et al., 1997, 2000). In a microeconomic analysis of U.S. biotechnology companies, Audresch and Stephan (1996) found that the physical proximity of academic research centres to biotechnology companies had a positive effect on the development of collaboratory links between them. Notwithstanding, they point out that this evidence is inconclusive and that long-distance relationships may be managed by companies willing to invest in collaboration with academic centres of research (Audretsch and Stephan, 1996). Consequently, two possible types of spillover may occur: horizontal, deriving from the location of a firm in a scientific environment; and vertical, resulting from collaboratory exchanges with the academic world. Vertical spillovers has been included with a dummy variable considering if the firm i is collaborating with a public institution to apply the patent.

To take into account the possible existence of horizontal spillovers, a set of variables that represent the regional scientific capability could be incorporated into the function Ski=f (.); in our case, we have chosen the expenditure per regional inhabitant destined to university research as the variable that summarises the efforts made towards strengthening the regional scientific base. The importance of these effects and the need to obtain more robust and reliable conclusions have led us in a second model to substitute this variable by fictitious regressors that will take the value 1 if the company i is located in a particular region, and 0 in contrary case. The problems of co-linearity in the data have led us to include the three regions that allocate most expenditure per inhabitant to university research (Navarre, Madrid and Catalonia). See Graph 1.

In table 1, each of these variables, its definition and statistical source are given.

Need and the ability to adopt and absorb scientific knowledge

Industrial sectors affected by rapid technological change and obsolescence tend to develop closer links with the scientific sphere than other industrial sectors. Various studies have indicated that scientific knowledge is relevant to industrial sector R&D in only a small number of industries: agriculture, chemicals, pharmaceuticals, electronics and precision instruments (Mansfield 1991; Jaffe 1989; Jaffe et al., 1993; Audretsch and Feldman 1996; Klevorick et al. 1995; Meyer-Krahmer and Schmoch, 1998). In other words, not all sectors of industrial activity have the same technological opportunities (Klevorick et al. 1993). The need to survive generates differences in the use of scientific and technological resources, and the latter are generally better utilised by those sectors faced with rapid technological change. However, in order for industry to be able to apply scientific knowledge, companies must first possess a certain capacity to absorb what knowledge is available, and this tends to be closely linked to the quality and the extent of the learning experiences afforded by scientific research and technological development (Cohen y Levinthal, 1989, 1990)[2]. Thus, R&D activities have a dual function; not only do they contribute to the development of new products and productive processes, they also reinforce the ability to learn (Scharginger et al., 2002).

In order to reflect the need and ability to absorb scientific knowledge empirically, we will employ variables that take account of the sector involved in the development of new technologies, the use of knowledge other than scientific knowledge, technological leadership and diversification. Table 1 contains a definition of each of these variables.

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[2] The concept of "absorptive capacity" was originally introduced by Cohen & Levinthal (1989, 1990) and was defined as the ability of a company to acknowledge, assimilate and apply new scientific information to the corporate innovatory process.

TABLE 1

DEFINITION OF EXPLANATORY VARIABLES	
Name	Definition
Requirements and capacity to absorb and adopt scientific knowledge	
Gji (j=1 to 4)	Binary variables which take account of the technological sector j (Group) in which company i files patents (see sectors in Table 1). Gji has a value of 1 if company i is in sector j (1 to 4), otherwise, the value is 0. The base category is Gji(j=5).
Di	Discrete variable which takes account of the number of sectors in which company i files patents. It represents the technological diversification of the company.
Lij	Continuous variable defined as the number of patents of company i in sector j, relativised by the total number of patents in the sectorial 'block' (of which there are 5) in which sector j is included. Relativisation has been effected on the basis of the number of patents per technological area (see Table 2) and not per sector, in order to avoid the bias which would be generated in the event that one sector presents only very few patent documents. It reflects the leadership of company i in sector j.
TKi	Discrete variable defined as the average number of patent citations drawn from the patent documents of company i. This variable takes account of any other sources of (technological) knowledge employed by the company, other than scientific knowledge.
Ci	Binary variable which has a value of 1 if company i has collaboraited with a university or public institution in submitting the patent; otherwise, the value is 0. This variable takes account of vertical spillovers of scientific knowledge.
Horizontal spillovers: Regional Opportunities for the transfer of scientific knowledge	
Ii	Continuous variables which take account of the spends of scientific research per inhabitant (lpc).
MADRIDi, CATALUÑAi, NAVARRAi	Dummy variables which have value 1 if the company i is located in each region; otherwise, the value is 0. Base category are the rest of Spanish regions. These three regions have a per inhabitant spenditure of scientific research higher than Spanish average (35%, 10% and 65%, respectively).
Source: own elaboration	

3. Econometric specification and hypothesis

The empirical treatment of the function of utilisation of scientific knowledge SKi=f(.) suggests various possibilities:

a) In the first place, we can assume that SK=y is a binary variable that describes the use (y=1) or non-use (y=0) of scientific knowledge (quantified by the presence of scientific citations in the patent). The modelling in function of the set of regressors X (that reflect the set of company capacities C, and scientific opportunities T) could be performed from a formulation of binary response (normal or logistic).

b) In the second place, the nature of the data suggests the formulation and estimation of a counting model to quantify intensity in the use of knowledge, by means of the number of citations (Poisson or negative binomial).

c) In the third place, the observation of the data, with a large number of zeros in the sample, leads one to think that possibly the process generating the data is formed by two regimes: One that traces the access to scientific knowledge and another that defines its intensity. Two categories of modelling can be utilised for the excess of zeros. One of these consists of estimating hurdle models suggested by Mullahy (1986). A more general formulation, introduced by Lambert (1992) and analysed in depth by Greene (1994) is the Poisson model with probability of zero increased (zero inflated Poisson model), where a zero result can be originated either by a binary process, or by a Poisson process.

Having put forward the theoretical framework, the basic hypotheses that we wish to test in this study are related to the possible effects of the regional scientific capabilities on the use of science by companies; we can specify these hypotheses as follows:

H1: *Regional expenditure on university research exercises a positive and significant effect on the use made of science by regional industry.*

H2: *The companies located in the regions that have invested most in academic research over the last decade present a greater utilisation of scientific knowledge than those companies located in a scientific environment to which fewer resources have been allocated.*

1. Data

In our evaluation of scientific knowledge use by private firms in Spain, we have undertaken an exhaustive review of the 1,643 patent applications filed by 1,129 companies, published between 1998 and 2001, inclusive. The number of observations relates to companies. Where a company has a number of different patents within the same sector, this has been treated as a single observation and is represented by the average number of scientific citations, patent citations, etc. Where a company has several patents in different industrial sectors, we have included one observation per industrial sector so that, subsequently, we might determine which sector each company relates to and which is the leading company within that sector. Taking this into account, the number of observations totalled 1,139.

Our primary information was obtained as follows. An exhaustive review was undertaken of all Spanish companies filing at least one patent application during the period from 1998-2001 (1,129 companies). The patents of each company were classified according to sufficiently diffuse criteria capable of distinguishing between five technological areas and thirty subfields based on the International Patent

Classification (IPC).[3] Of all the patent documents examined, a total of 163 (9.92%) include NPCs (references to scientific literature, text books and other citations) relating to 79 companies (6.99% of those filing patents). The NPC references recorded for these 163 patents amounted to 1,427 citations, of which 969 related to scientific journals included in the Institute for Scientific Information (ISI) Current Contents; consequently, 67.90% of all the NPC references correspond to what is generally accepted as "quality scientific research".

-TABLE 2-

PATENTS, FIRMS, NON PATENT CITATIONS (NPC) AND PATENT CITATIONS (PC) BY TECHNOLOGY SECTOR (1998-2001)

TECHNOLOGY SECTOR	PATENTS		FIRMS			NPC			
	Nº	ESP=100	Nº	ESP=100	Nº PAT/ Nº FIRM	TOTAL Nº	TOTAL ESP=100	ISI ESP=100	%ISI/ TOTAL
I. ELECTRICAL ENGINEERING									
1. Electrical machinery and apparatus, electrical energy	139	8,46	68	6,02	2,04	4	0,28	0,21	50,00
2. Audio-visual technology	37	2,25	27	2,39	1,37	0	0,00	0	-
3. Telecommunications	57	3,47	32	2,83	1,78	8	0,56	0,1	12,50
4. Information technology	13	0,79	12	1,06	1,08	0	0,00	0	-
5. Semiconductors	4	0,24	3	0,27	1,33	0	0	0	-
II. INSTRUMENTS									
6. Optics	7	0,43	3	0,27	2,33	0	0	0	-
7. Analysis, measurement, control technology	127	7,73	83	7,35	1,53	12	0,84	0,62	50,00
8. Medical technology	54	3,29	42	3,72	1,29	11	0,77	0,52	45,45
III. CHEMISTRY, PHARMACEUTICALS									
9. Organic fine chemistry	80	4,87	36	3,19	2,22	500	35,04	37,87	73,40
10. Macromolecular chemistry, polymers	10	0,61	9	0,8	1,11	8	0,56	0,31	37,50
11. Pharmaceuticals, cosmetics	58	3,53	33	2,92	1,76	221	15,49	16,2	71,04
12. Biotechnology	26	1,58	10	0,89	2,6	466	32,66	34,16	71,03
13. Materials, metallurgy	42	2,56	32	2,83	1,31	35	2,45	0,72	20,00
14. Agriculture, food chemistry	56	3,41	51	4,52	1,1	67	4,70	4,85	70,15
15. Chemical and petrol industry, basic materials chemistry	34	2,07	25	2,21	1,36	58	4,06	2,99	50,00
IV. PROCESS ENGINEERING, SPECIAL EQUIPT.							0,00		
16. Chemical engineering	40	2,43	34	3,01	1,18	6	0,42	0,1	16,67
17. Surface technology, coating	19	1,16	19	1,68	1	9	0,63	0,62	66,67
18. Materials processing, textiles, paper.	74	4,5	58	5,14	1,28	0	0,00	0	-
19. Thermal processes and apparatus	37	2,25	20	1,77	1,85	0	0,00	0	-
20. Environmental technology	26	1,58	24	2,13	1,08	5	0,35	0,31	60,00
V. MECHANICAL ENGINEERING, MACHINERY									
21. Machine tools	52	3,16	38	3,37	1,37	0	0,00	0	-
22. Engines, pumps and turbines	23	1,4	16	1,42	1,44	3	0,21	0	0,00
23. Mechanical elements	46	2,8	29	2,57	1,59	0	0,00	0	-
24. Handling, printing	138	8,4	104	9,21	1,33	0	0,00	0	-
25. Agriculture and food processing, machinery and apparatus	70	4,26	58	5,14	1,21	9	0,63	0,41	44,44
26. Transport	79	4,81	53	4,69	1,49	0	0,00	0	-
27. Nuclear engineering	2	0,12	2	0,18	1	0	0,00	0	-
28. Space technology, weapons	10	0,61	7	0,62	1,43	0	0,00	0	-
29. Consumer goods and equipment	144	8,76	100	8,86	1,44	5	0,35	0	0,00
30. Civil engineering, building, mining	139	8,46	101	8,95	1,38	0	0	0	-
TOTAL	1.643	100	1.129	100	1,46	1.427	100	100	67,90

FUENTE: O.E.P.M. y elaboración propia.

[3] This classification was devised jointly by FhG-ISI, the French Patent Office (INPI), and the Observatoire des Sciences et des Techniques (OST).

Table 2 gives in detail the basic information classified by sectors. It presents the sectorial distribution of the number of patents, the number of companies that have applied for the patents, and the total number of scientific citations (NPC).

Tables 3 and 4 contain the basic data to enable some overall lines of interest on the regional diversity of science-technology flows to be assessed:

- As can be appreciated in table 3, Catalonia, Madrid and Navarre are, in this order, the three autonomous regions that account for the largest flows, with the 69.53% of the NPC citations, and 71.61% of the scientific citations (ISI). The concentration of citations is greater than that of the number of patents (these same three regions account for 62.93% of the patents), which leads one to think that the concentration of science-technology flows is even more polarised territorially than the technology itself.

-The ratio of distribution of the number of citations in relation to the distribution of the number of companies (see %NPC/EMP in Table 3) gives us a general picture of the degree of regional concentration of flows, by companies. Madrid, Andalusia and Navarre present indicators higher than unity, this denoting a greater concentration of flows in relation to the number of companies that seek patents. It is interesting to see in table 2 that a figure almost three times the national average corresponds to Navarre: this region has only 3.52% of the companies that patent, but accounts for 10.43% of the NPC citations and 10.84% of the ISI citations. The opposite pattern of behaviour is presented by the Region of Valencia, which has 11.44% of the total companies that patent, but accounts for only 3.64% of the NPC citations.

- Table 3 gives the ratios of the number of scientific ISI citations, to the total number of NPC citations. The Basque Country, Navarre, Madrid and Catalonia, in this order, are the autonomous regions that utilise "quality science" in greater proportion than the rest (with ratios of ISI citations to NPC citations of around 70%). It should be observed, finally, in the last column of Table 3, that the proportion of NPC citations and the proportion of PC citations in the national total present an inverse relationship. Navarre, Madrid and Andalusia have values lower than unity; in other words, in relative terms (in relation to the Spanish average), for the totality of sectors, these regions are more intensive in scientific than in technological knowledge; while in other autonomous regions such as Catalonia, the Basque Country and Valencia, where technological change is supported more by the development of previously patented technology (citations of patents), relatively less use is made of scientific knowledge.

- With the object of avoiding the bias introduced by the aggregation of all the sectors, some indicators of regional concentration have been calculated for the sectors that incorporate most scientific citations in patent documents, and the level of concentration of patents has been obtained for those regions that account for most of these flows (Table 4). It can be seen that science-technology relationships measured by this indicator are strongly polarised. Furthermore, a relationship between concentration of technology (patents in a sector) and science-technology flows (scientific citations in the patents of the same sector) does not necessarily exist; for example, in the sector 11 "Pharmaceutical and cosmetic products", the region accounting for the most citations is Navarre, with 45.86% (ISI) of the national total, while in volume of patents, this sector represents only 5.17% of the national total (see DR1); if we sum the two regions that cite most, Navarre and Catalonia, together they account for 82.17% in number of ISI citations, and 62.07% in number of patents (see DR2). A similar situation occurs in sector 14, "Agriculture and food chemicals", where Castile y Leon is the region that produces most scientific citations (27.66%), but with a national participation of only 5.36% in the number of patents in this sector; the two regions with most citations are Castile y Leon and Andalusia, together accounting for 55.32% of the national total of scientific citations, and 12.50% of the total national patents. These descriptive data suggest that the overall tendency of concentration in these flows is conditioned by the relative weight of technological sectors with high propensities to cite scientific literature and of traditional sectors where advances are basically supported by previously patented technology.

-TABLE 3 -

PATENTS, FIRMS AND SCIENTIFIC CITATIONS (NPC)1998-2001
REGIONAL DISTRIBUTION

REGION	PATENTS		FIRMS (*)		NºPAT/ NºEMP	CITAS NPC						%NPC/ %EMP	CITAS PC		%NPC/ %PC
	TOTAL	ESP=100	TOTAL	ESP=100		TOTAL	Nº/PAT	TOTAL ESP=100	ISI	ISI ESP=100	%ISI/ TOTAL		Nº	ESP=100	
ANDALUCÍA	73	4,44	54	4,75	1,35	119	1,63	8,33	65	6,7	54,62	1,75	60	3,66	0,44
CATALUÑA	603	36,7	401	35,3	1,5	480	0,8	33,61	333	34,36	69,38	0,95	641	39,09	1,16
MADRID	341	20,75	245	21,57	1,39	364	1,07	25,49	256	26,41	70,33	1,18	335	20,43	0,80
PAÍS VASCO	146	8,89	99	8,71	1,47	85	0,58	5,95	65	6,7	76,47	0,68	162	9,88	1,66
VALENCIA	170	10,35	130	11,44	1,31	52	0,31	3,64	22	2,27	42,31	0,32	161	9,82	2,70
NAVARRA	90	5,48	40	3,52	2,25	149	1,66	10,43	105	10,84	70,47	2,96	85	5,18	0,50
RESTO	220	13,39	167	14,7	1,32	179	0,81	12,54	123	12,69	68,72	0,85	196	11,95	0,95
TOTAL	1.643	100	1.136	100	1,45	1428	0,87	100	969	100	67,86	1	1.640	100	1

(*) Number of firms differs from Table 1 because the location of a firm in two regions if we consider national or regional level.

SOURCE: O.E.P.M. and own elaboration.

The basic data of the explanatory variables incorporated in the models are given in table 4.

-TABLE 4-

REGIONAL DIVERSITY OF TECHNOLOGY (PATENTS) AND OF SCIENCE-TECH FLOWS (NPC) (*)

SECTOR TECNOLÓGICO	PATENTES (**)				CITAS NPC							
					TOTAL				ISI			
	DR1	DR2	DR4	HR	DR1	DR2	DR4	HR	DR1	DR2	DR4	HR
9. Química orgánica fina	68,75	88,75	96,25	0,77	62,40	91,20	97,60	0,74	59,40	91,55	97,82	0,72
11. Productos farmacéuticos, cosmética	5,17	62,07	89,66	0,65	39,37	76,02	96,83	0,59	45,86	82,17	97,45	0,64
12. Biotecnología	34,62	53,85	76,92	0,47	34,76	55,79	81,12	0,46	34,74	52,87	79,46	0,45
14. Agricultura, química alimentaria	5,36	12,50	50,00	0,36	35,82	56,72	89,55	0,50	27,66	55,32	87,23	0,47
TOTAL	36,70	57,46	65,12	0,44	33,66	59,19	79,45	0,45	34,37	60,78	81,32	0,46

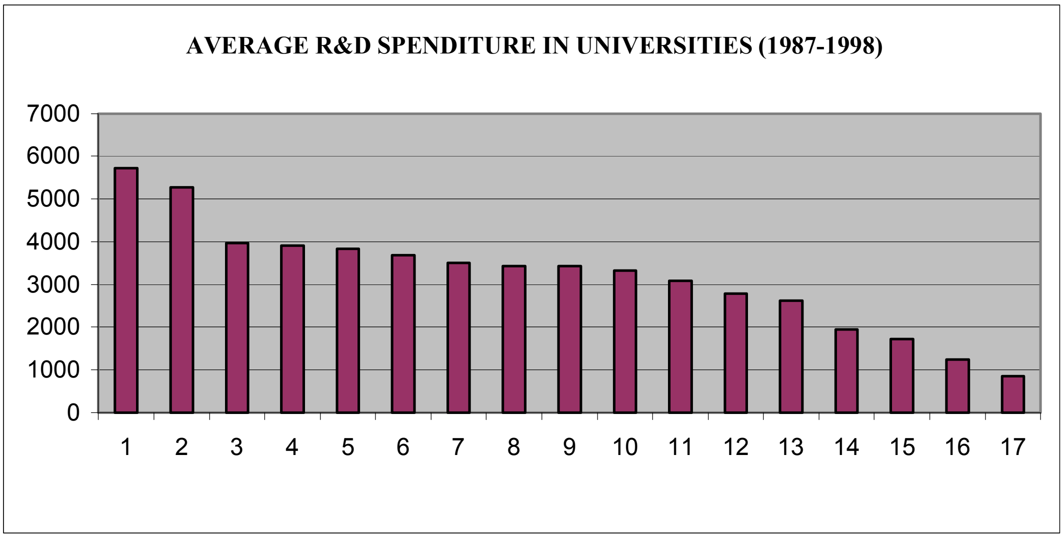
(*) Technological sectors with more than 30 scientific citations.

(**) DR1, DR2 y DR4 is patent concentration in the regions with the higher concetnration in ISI scientific citations (DR1), those two regions with the highest concentration (DR2) and those four regions with the highest concentration (DR4). HR is Herfindalh index; it is computed for the 17 Spanish regions.

SOURCE: Own elaboration.

Of the variables described in table 1, the regressor I (regionalised expenditure on university research) is of special interest, this being the central point of the hypothesis to be tested. Graph 1 presents the average expenditures per inhabitant in the period 1987-1998 for the various Spanish regions. A greater "regional effort in university research" in Navarre, Madrid and Catalonia can be appreciated; the location of companies in these regions is the qualitative variable introduced in the second group of models to quantify possible horizontal spillovers.

GRAPH 1



2. Results

With the object of making the results more robust, all the modellings (a, b and c) formulated in the econometric specification part of this paper have been run. Two groups of regressions have been obtained to test hypotheses H1 and H2. In the first group (Table 5), the expenditures of the region where the company i carries out its activities are included as explanatory factor. The findings from this table are:

a) First, the logit model results indicate the probability of use or non-use of scientific knowledge by each company, independently of the intensity of use. All the variables are statistically relevant except G1. The signs obtained for the coefficients are those expected. The data suggest that the probability of the application of scientific knowledge in the technology patented by the companies increases in proportion with the growth of the financial resources allocated to university research. This model therefore tends to support hypothesis H1. With respect to the rest of the variables, it can be observed that the probability that industry will apply scientific knowledge increases with the degree of technological diversification of companies and technological leadership. There is a relationship, also positive and significant, between the probability of applying scientific knowledge and the level of technological knowledge. Collaboration between private industry and university in the process of development of the technology patented also increases the probability that companies will apply scientific knowledge. Finally, the significance of the coefficients of the variables G2, G3 and G4 suggests that there are also relevant sectorial differences in the application or use of scientific knowledge in industry.

b) Secondly, estimations were obtained for two count data models (Poisson and Negative Binomial). The models estimated using a Poisson or NB distribution consider the number of scientific citations in the patents to be a count variable and, consequently, are able to quantify the intensity in the use of scientific knowledge. In the case of the Poisson model, the application of the over-dispersion test developed by Cameron & Trivedi (1990) (based on a t statistic) with a sampling value of 4,009 suggests the presence of over-dispersion in the data. The assumption of equality of means and variance is not compatible with the data, so it would therefore appear reasonable to pass to the estimation of the binomial negative. The over-dispersion parameter (alpha) is statistically significant, suggesting that an NB modelling of the process may be a suitable means of representing the data. The coefficient of the variable I is also statistically significant, and thus the adequacy of this model would suggest that regional expenditures on university research would also be associated with the intensity in the application of scientific knowledge by companies. The rest of the variables with statistically significant coefficients present parameters with expected signs. The coefficient of the variable L (technological leadership) is negative (which does not appear reasonable), but it should be observed that this is not significant.

TABLE 5

MAXIMUM LIKELIHOOD ESTIMATES							
Variables	LOGIT	POISSON	NB	ZIP (Zero infl)	ZIP (Poisson)	ZINB (Zero inf)	ZINB (NegBin)
Cte.	-7.956 *	-5.733 *	-7.048 *	3.759 *	2.163 *	7.715 *	1.321 *
TK	0.173 *	0.033 *	0.143 *		-0.044 *		-0.001
D	0.343 *	0.249 *	0.406 *		0.031		0.224
L	41.397 *	31.143 *	-32.684		-3.456		12.140
C	2.694 *	1.384 *	1.610 *	1.411 *	0.275 *	3.164 *	0.589
G1	0.545	1.473 *	1.803 *	0.254		0.803	
G2	1.875 *	2.293 *	2.702 *	0.778 *		1.990 *	
G3	4.348 *	5.207 *	5.345 *	2.153 *		4.847 *	
G4	1.687 *	2.099 *	1.602 *	0.741 *		1.952 *	
I	0.262 *	0.139 *	0.296 *	0.170 *		0.388 *	
Alpha			9.312 *				
Nº obs.	1139	1139	1139		1139		1139
Rest. Log. L.	-314.755	-2387.804	-1218.745				
Log. L.	-179.002	-1218.745	-498.995		-658.69		-
Chi-sq.	271.548 *	2338.119 *	1439.499 *				
Pseudo R2	0.431						
RsqP		0.627					
RsqD		0.524					
Overdisp test (1)		4.009					
Vuong test					6.145		6.979
*Sign. 5%. **Sign. 10% . (1) Based on Cameron and Trivedi (1990).							

c) Lastly, the estimations for the models ZIP and ZINB have been obtained. When the data generating process is characterised by a dual regime, the NB distribution may indicate a spurious over-dispersion. Consequently, ZIP or ZINB specification analysis would be appropriate to determine the possibility of mixed distributions. With the presence of two regimes, we can assume that one will be determined by the needs and opportunities for access to scientific knowledge, and the other will determine its intensity. The needs are reflected by means of sectorial binary variables (G1, G2, G3 and G4), and the opportunities by means of the variables associated with the regional expenditure on universities (I) and the possibility of collaboration in the development of the patent with the university (C). The degree of intensity with which scientific knowledge is applied, is taken in through company variables, together with determinants of competence (D, L, TK), and through the variable reflecting collaboration with the university (C), which not only gives companies access to certain types of scientific knowledge but can also influence the intensity in the use of knowledge.

TABLE 6

MAXIMUM LIKELIHOOD ESTIMATES							
Variables	LOGIT	POISSON	NB	ZIP (Zero infl)	ZIP (Poisson)	ZINB (Zero inf)	ZINB (NegBin)
Cte.	-6,873 *	-5,108 *	-5,496 *	-5,920 *	2,086 *	-5,805 *	1,429 *
TK	0,183 *	0,044 *	0,142 *		-0,049 *		-0,011
D	0,366 *	0,261 *	0,379 **		0,016		0,187
L	2,919	3,139 *	-0,257		2,024 *		2,596
C	2,855 *	1,452 *	1,454 **	2,700 *	0,271 *	3,192 *	0,510
G1	1,035	1,808 *	1,880 *	0,877		0,916	
G2	2,224 *	2,496 *	2,798 *	2,019 *		2,068 *	
G3	4,551 *	5,325 *	5,361 *	4,585 *		4,826 *	
G4	1,929 *	2,249 *	1,692 *	1,916 *		1,943 *	
CATALUNYA	1,080 *	0,267 *	0,303	1,135 *		1,234 *	
MADRID	0,620	0,252 *	0,767 **	0,718 **		0,837 *	
NAVARRA	1,522 *	1,617 *	1,959 *	1,576 *		1,748 **	
Alpha			9.329 *				
Nº obs.	1139	1139	1139		1139		1139
Rest. Log. L.	-314.755	-2387.804	-1179.667				
Log. L.	-177.381	-1179.667	-497.996		-652.753		-
Chi-sq.	274.787 *	2416.275 *	1363.342 *				
Pseudo R2	0.436						
RsqP		0.646					
RsqD		0.541					
Overdisp test (1)		3.788					
Vuong test					6.314		6.911

*Sign. 5%. **Sign. 10%. (1) Based on Cameron and Trivedi (1990).

It can be observed that, for both the ZIP and the ZINB models, the Vuong statistic supports the model with two regimes, against the Poisson or NB models.

Between the ZIP and the ZINB, the latter provides better-fitted predictions of the number of zeros. In any case, both specifications support hypothesis H1[4].

In the second group of regressions, the companies located in the regions with a larger expenditure on university research per inhabitant have been discriminated, using binary variables (Table 6). The tests of specification and the estimations follow very similar lines to the preceding group. Most of the models tend to support hypothesis H2 for the three regions considered.

The joint analysis of the results obtained in all the specifications is summarised in table 7, where the hypotheses, the variables representing each, and the effects (positive/negative) in each model, are given.

-TABLE 8-

HYPOTHESIS CONTRAST

Hypothesis	Explanatory Variables	LOGIT		POISSON		NEGATIVE BINOMIAL		ZIP		ZINB	
		Relation	Sig (1)	Relation	Sig (1)	Relation	Sig (1)	Relation	Sig (1)	Relation	Sig (1)
H1	I	+	*	+		+	*	+	*	+	*
H2	CATALUÑA	+	*	+		+		+	*	+	*
	MADRID	+		+		+	**	+	**	+	*
	NAVARRA	+	*	+	*	+	*	+	*	+	**

(1) *: 5%; **:10%.
Source: own elaboration

3. Conclusions

The principal objective of this work is to determine if the regional expenditures allocated to building a strong scientific capability are related to a greater utilisation of the results of academic scientific research on the part of those companies that generate patentable technology. Our main conclusions can be summarised as follow:

* The models tends to support hypothesis H1: *Regional expenditure on university research exercises a positive and significant effect on the use made of science by regional industry.*

And most of the models support the hypothesis H2: *The companies located in the regions that have invested most in academic research over the last decade present a greater utilisation of scientific knowledge than those companies located in a scientific environment to which fewer resources have been allocated.*

*With respect to the rest of the variables, it can be observed in some models that the probability that industry will apply scientific knowledge increases with the degree of

[4] It should be taken into account that the negative signs of the logit specification of the ZIP occur because the value 1 is assigned when y=0, and value 0 when y>0.

technological diversification of companies and technological leadership. There is a relationship between the probability of applying scientific knowledge and the level of technological knowledge. Collaboration between private industry and university in the process of development of the technology patented also is a relevant variable in all models. Finally, the significance of the coefficients of the variables G2, G3 and G4 suggests that there are also relevant sectorial differences in the application or use of scientific knowledge in industry.

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