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University research and the location of patents in Spain

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UNIVERSITY RESEARCH AND THE LOCATION OF PATENTS IN SPAIN [a] [b]

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ABSTRACT: The main purpose of this paper is to analyse the relationship between innovative capacity and the presence of innovative inputs at a geographical level in Spain. Within the framework of a Griliches-Jaffe knowledge production function the effects of university research on corporate patents in four high and medium technology sectors are explored. In contrast to other studies carried out on this subject in the United States, the results do not provide evidence, except in the electronics industry, to support a positive relationship between university research and regional innovation

Keywords: knowledge spillovers, universities, geography of innovation, R&D
JEL Classification: O30, O18, R30, R58

RESUMEN: El principal objetivo de este documento de trabajo es analizar la relación entre los resultados innovadores y la presencia de inputs innovadores a nivel regional en España. A partir de la denominada función de producción de conocimientos tecnológicos Griliches-Jaffe se examinan los efectos de la investigación universitaria sobre los resultados innovadores de cuatros sectores de contenido tecnológico medio y alto. En contraste con otros estudios llevados a cabo para el caso de los Estados Unidos, los resultados no muestran, a excepción de en la industria electrónica, una influencia positiva de la investigación universitaria sobre los resultados innovadores de las regiones.

Palabras clave: externalidades del conocimiento, universidades, geografía de la innovación, I+D

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1. Introduction

The relationship between science and technology, and specifically between academic research and technology, has been frequently analysed and it is a controversial one. In the so-called linear model of innovation technological progress is preceded by scientific discoveries. However theoretical and empirical analysis have pointed out that the relationship between scientific progress and technological advances is more complex, there is interaction in both directions and sector differences are considerable. For example, Pavitt (1984) shows that scientific advances are specially important as a source of innovative ideas only in specific industries like electronics or pharmaceuticals, the so-called science-based sectors. Rosenberg (1976, 1982) questions the causal relation between science and technology and states that a scientific system with a high level of quality is not a necessary condition for technological dynamism. He also shows that on many occasions technological progress is previous to scientific discoveries. Freeman (1988), on the other hand, says "... it is not actually essential to be the world leader in technology. It is necessary to have a strong capability in basic research in order to assimilate and advance most important technologies today".

A combination of empirical and theoretical work has recently analysed the relationship between geography and innovation. An emerging literature has focused on the importance of proximity for the transmission of knowledge derived from academic research. For example, Pavitt (1998) states that: "the links between basic research and technological practice are geographically constrained". The empirical analysis made, mainly in the United States, has shown that university research positively influences the innovative output of nearby firms.

The main objective of this paper is to examine whether Spanish universities affect the spatial location of innovative corporate outputs. Universities have experienced significant growth and territorial expansion, with the creation of new universities, in the last decade. This paper is organised as follows. Firstly, the main channels between academic research and technological activities are presented. Also the ways in which universities can foster regional growth are examined. Secondly, the spatial distribution of Spanish universities is presented. Finally, the relationship between innovative activity and university research is, through an empirical analysis, examined.

2. University research and geography

The contribution of basic research to technological innovation and the relationship between universities and industry take place in different ways (Mowery, 1995; Florax, 1992; Rosenberg and Nelson, 1994, Pavitt 1998). These are (Pavitt, 1998) mainly obtaining, through academic research, useful knowledge inputs, the training of scientists and engineers, the background knowledge of academic researchers acquired through their training and experience, participation in national and international professional networks and the creation of new firms or spin-offs based on discoveries made in universities.

Therefore the various possibilities for interaction between academic research and the technological activities of firms allow the reasons why geographical distance may have a relevant role to be explained. While distance does not have any influence on the accessibility of published results there are other knowledge transmission channels that lead to a geographical agglomeration of the benefits of university research. This happens especially when the transfer of knowledge, frequently tacit, requires interaction between agents, personal mobility and frequent contact (Pavitt, 1998).

Contrary to the approach that new knowledge is a public good that is easily accessible and has very few transmission costs, empirical evidence shows that this view is limited. As Audrestch and Feldman (1996) point out, although the cost of transmitting information may not change with distance, the cost of transmitting knowledge rises with distance. This distinction between information and knowledge is a fundamental one for analysing the importance of proximity in the transmission of spillovers. While information is easy to codify, the transmission of knowledge requires frequent contacts and the interaction of agents (Audrestch, 1998). R&D activities will be more efficient when firms and universities are near to each other because this will allow them to share resources and to interact easily (Verspagen, 1997). Also, a large part of innovations have their origin in cities (Jacobs, 1986), which shows the importance of interaction between individuals and firms in generating and adopting new technologies. As Glaeser et al. (1992) say “after all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents”.

The role of universities in fostering regional growth has been studied with different approaches. The accessibility of knowledge infrastructures is an explanatory variable of the location decisions of firms, of corporate innovative activity, and of regional growth. Florax (1992) distinguishes between three approaches to analysing the regional impact of universities. These approaches are:

1) Firm location analysis. Although the results of applied studies are not definitive, proximity to universities has been considered a significant factor in firm location decisions, especially in high-technology firms, and in the location of the laboratories of R&D firms (Jaffe, 1989; Bania, Calkins and Dalenberg, 1992, Florax, 1992; Sivitanidou and Sivitinades, 1995). Some studies have also stated that the proximity of academic researchers is an explanatory variable of the creation of new high-technology firms. However, Bania, Eberts and Fogarty (1992) do not find evidence to support the view that universities influence the creation of new high-technology firms positively.

2) Research on the spatial distribution of innovations with the objective of examining differences in regional innovative activity. Again, the existence of technological and scientific infrastructure is a relevant factor. Studies on innovative "milieux" may be included (Perrin, 1992) in this group. Also, in the well known case of Silicon Valley (Saxenian, 1994) the role of the university in fostering innovative regional ability is affirmed. Castells (1992) examines innovative regional dynamism and proposes a typology of technological innovation media where he stresses the importance of the presence of academic research centres for regional innovation capacity. However, as Florax (1992), points out, most of these analyses are based on case studies, with the use of surveys and interviews, which limits the possibility of arriving at general conclusions on the influence of universities on regional innovative capacity.

3) Economic models of regional growth, based on a production function. In these models the knowledge-base, measured, for example, by the existence of universities, is introduced as an explanatory variable of regional differences in income and productivity. In this approach, of note are the studies which within the framework of a production function use a measure of innovations as a dependent variable and a group of possible explanatory variables, all of them for the same geographical area (Feldman, 1999). Specifically, these studies use the knowledge production function proposed by

Griliches (1979, 1990) and introduce the spatial dimension to examine the importance of geographical proximity for transmitting spillovers. The subjacent hypothesis in this approach is that innovative activity and output will agglomerate in those regions where knowledge inputs are greater due to the fact that knowledge transfer is easier with geographical proximity (Feldman, 1999).

The basic specification of these models (Audrestch, 1998; Feldman, 1999) is:

$$\log INN_{ij} = \beta_0 + \beta_1 \log GID_{ij} + \beta_2 \log UNIV_{ij} + \varepsilon_{ij} \quad (1)$$

where INN measures innovative output for geographical areas and industries, GID is private expenditures on R&D and UNIV is an indicator of university research, R&D expenditures or R&D personnel. Therefore, in contrast to the usual approach, where the observation unit is the firm, in this approach the unit of observation is at the spatial level.

The first study with this approach was made by Jaffe (1989) in which the importance of proximity in the transmission and capture of spillovers generated in universities is affirmed. As Jaffe (1989) points out, it is reasonable to think that there are spillovers from universities to firms and although the means of transmission are not well known distance may play an important role.

This production function may be considered an empirical model because from a theoretical viewpoint there is no specific framework in which to study the existence of local spillovers or to analyse the regional distribution of innovative activities. Using this function, known as a Griliches-Jaffe knowledge production function, some empirical studies have been done (Acs, Audrestch and Feldman, 1992; Feldman 1994; Anselin, Varga and Acs, 1997a and 1997b; Varga, 1998, Blind and Grupp, 1999), with the objective of analysing the location determinants of innovations and the influence of university research. The main conclusion of these studies is that proximity is important and that university research influences regional innovative capacity positively.

3. Universities in Spain

In Spain, universities are one of the main agents of R&D expenditures. Specifically, in 1995, 32 per cent of R&D expenditures was made by universities and in 1998 the percentage was nearly 31 per cent, both of which were clearly higher than the 20 per cent recorded in the early nineties. Between 1990 and 1999 there was significant growth and territorial expansion in the university system in Spain. Currently there are 63 universities, 23 of which were created after 1989.

In comparison with other countries the percentage of R&D expenditures made by the universities in Spain is clearly higher. In comparison to 32 per cent in Spain in 1995, in the European Union it was 20.8 per cent and in the OECD countries this percentage was still lower, at 17.3 per cent (OECD, 1999). Nevertheless the fact that the research effort in Spain is lower than in the European Union, or in relation to the total for the OECD countries, has to be taken in account. R&D expenditures as a percentage of GDP was 0.85 per cent in 1995, far from the 1.84 per cent corresponding to the European Union or the 2.16 per cent for the total OECD.

R&D distribution between the agents of expenditure, -firms, public administration, universities, and non-profit organisations- shows considerable regional -Autonomous Community- differences. Universities are the main agents of R&D expenditures in nine regions, with percentages higher than 50 per cent. Academic research, despite the agglomeration in Madrid and Catalonia, is where the spatial concentration is least, as shown by Herfindhal index. Therefore, the expansion of the universities has led to a territorial redistribution of innovative activities (Buesa, 1998).

Table 3.1. Spatial concentration of R&D expenditures

R&D expenditure	**Herfindhal (1)**
- Public sector	0.3721
- Universities	0.1183
- Firms	0.2603
- Total	0.2139

(1) Herfindhal indexes by regions
Source: Buesa (1998)

The universities as has been pointed out made research in various scientific fields with an uneven commercial and industrial applicability. Therefore, no all university research results in useful knowledge for firms which pursue a commercial application. However research in some specific fields has to be a relevant source of information and ideas for some commercial activities, increasing technological opportunities and private R&D productivity (Nelson, 1986; Von Hippel, 1988).

Therefore, it is interesting to examine the spatial distribution of the academic research more related to firms. In Spain there is no information about the university research expenditure by Departments from which it is possible to define the research relevant to industrial activities. However, the National Statistical Institute (INE, 1997) classifies the R&D personnel and expenditures into scientific fields. This allows the examination of the regional distribution of university research by scientific fields.

Table 3.2. Regional distribution of R&D university expenditures by scientific fields.

	Total	**1. Maths and natural sciences**	**2. Engineering and technology**	**3. Medicine**	**4. Agricultural sciences**
Andalusia	15.66	15.85	8.30	14.17	28.89
Aragon	3.00	3.29	4.41	1.03	6.94
Asturias	3.04	2.28	2.65	3.77	3.84
Balaeric Isles	1.01	1.74	0.16	0.56	1.06
Canary Isles	3.79	4.36	3.53	5.77	2.44
Cantabria	1.47	1.25	2.96	2.43	0.00
Castilla y Leon	6.86	8.07	4.62	7.81	8.30
Castilla-La Mancha	1.39	1.81	0.38	0.10	4.11
Catalonia	17.85	18.52	20.09	11.08	9.02
Comunidad Valenciana	9.89	10.57	10.95	12.84	3.55
Extremadura	1.13	0.96	0.43	0.94	3.09
Galicia	5.66	4.60	6.02	5.89	8.56
Madrid	20.32	19.62	28.51	19.94	8.89
Murcia	2.08	2.08	1.13	2.44	7.89
Navarra	1.93	0.81	2.55	4.19	2.38
The Basque Country	4.60	3.82	3.27	6.74	0.00
Rioja, La	0.31	0.37	0.03	0.32	1.05
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: own elaboration with information provided by the INE

The spatial distribution of university R&D expenditures by scientific fields does not show, except in the case of agricultural sciences, substantial differences compared with the regional distribution of the whole of university R&D expenditures. With the creation of new universities and the expansion of universities, R&D activities in every scientific field are carried out in almost all regions. The most important differences are in agricultural sciences, where 30 per cent of R&D expenditures is concentrated in

Andalusia. Also in engineering and technology, where there was traditionally a great concentration in Madrid and Barcelona, Madrid continues to contain 28 per cent of the university R&D expenditures. In some disciplines, like electrical and electronic engineering, the weight of Madrid is also considerable, at over 30 per cent.

4. Theoretical framework and empirical analysis for Spain

The usual theoretical framework in the economic literature for the econometric analysis of processes of innovation and technological spillovers from R&D activities is based on the knowledge production function proposed by Griliches (1979, 1990). This function is supported by abundant empirical evidence and has been the basis for many applied studies (Audrestch, 1998).

The analysis for the Spanish case is based on this model and on the empirical analyses that use models where the geographical innovative output depends on the presence of innovative inputs (Jaffe, 1989; Feldman, 1994), as has been mentioned in the previous section.

With this approach the matters to analyse are the examination of the importance of proximity in knowledge transfer and the factors that explain the location of innovations in a territory and specifically to study the influence of university research on the spatial distribution of innovations. Then the purpose is to analyse whether the benefits of university research are, in Spain, geographically localised, as is shown by the previous empirical studies and an abundant literature (Lundvall, 1992; Nelson, 1993; Pavitt, 1998). The basic hypothesis is that knowledge generated by university research is frequently tacit and then proximity may be important in its transmission. This transmission allows the productivity and efficiency of R&D activities of firms to be increased and positively influences the solution of technological problems (Nelson, 1986; Pavitt, 1998).

Two kinds of specifications have been considered. In the first one, with the objective of examining the influence of university research as a whole, no sectoral distinction has been considered. In the second case some specific industries have been selected.

For the first case, the use of a unit of observation at a spatial level without disaggregation of industries allows different spatial units to be considered. Two spatial units have been used, provinces (NUTS-3) and regions (NUTS-2). The determination of the correct unit is a controversial subject. The statistical constraints have led to the use of geographical units that are larger than theoretically preferable. Most studies agree in pointing out that the preferable unit is the city or metropolitan area because it is in these that the interaction and knowledge exchange between the various agents usually takes place. In the Spanish case statistical constraints make the use of cities or metropolitan areas as the unit of analysis impossible. Then its seems convenient to use two alternatives, and a data base has been constructed with information for provinces to compare with the results obtained by regions.

For regions there is statistical information that allows the use of different variables for the inputs considered. Specifically, private effort in innovation can be measured in two ways. The first is the usual R&D expenditures (GID) performed by the business enterprise sector (INE, 1997). The second is, with a more broad concept of innovation, the total expenditures on innovation (GINN) made by firms from the survey carried out by the INE (1998). In this case the expenditures on innovation, on the basis of the directives of the Oslo manual (OECD, 1992, 1997), includes, together with expenditures on R&D, other types of expenditure that form part of the process of innovation such as the acquisition of non-material technology, and expenditure on industrial design or industrial engineering. In the case of university research two measures can also be used, R&D expenditures (UNIVG) and R&D personnel (UNIVPE). To measure innovative output there is only one possibility which is to use applications for patents. This indicator, despite its deficiencies, has been the most common in economic literature. On the other hand, the only available information to measure the effort of firms and universities in provinces is expenditures on innovation as a measure for firms, and R&D personnel as an indicator of university research.

The model is:

$$INNOV_i = f\,(GRD_i, UNIV_i) \qquad (2)$$

where $INNOV_i$ is an indicator of innovations -corporate patents (PAT_i)- of a geographical area, GRD_i is an indicator of the private resources on innovation (GID_i or $GINN_i$) and $UNIV_i$ is the university research, R&D expenditures or personnel.

For estimation purposes the common specification in the literature has been used, a Cobb-Douglas production function, with the use of population (POB) as a control variable, due to the different sizes of regions and provinces (Jaffe, 1989). The results are presented in Table 4.1, the first four columns being the estimations for regions and the last one for provinces, excluding the observations without universities.

Table 4.1. Estimation results (logarithms). Regions and provinces

	PAT	PAT	PAT	PAT	PAT
C	-9.6995 (-4.667)	-13.2969 (-5.321)	-7.0292 (-2.047)	-9.700 (-4.667)	-14.7342 (-4.791)
GINN	0.5852 (2.863)*	0.6216 (3.044)*			0.4883 (5.243)*
GID			0.5118 (4.186)*	0.5353 (4.401)*	
UNIVPE	0.5953 (1.524)		0.3329 (0.970)		0.0434 (0.207)
UNIVG		0.5183 (1.265)		0.2291 (0.639)	
POB	-0.199 (-0.460)	-0.169 (-0.356)	-0.0161 (-0.045)	0.0587 (0.149)	0.656 (2.077)*
N	17	17	17	17	41
R^2 –adj	0.779	0.768	0.847	0.841	0.713
White	6.550	5.893	1.743	1.390	5.832

t-values in parenthesis. * indicates significance of at least 95%.

Both R&D expenditures by firms and corporate expenditures on innovation have positive and statistically significant coefficients. The elasticities are quite similar to those obtained in other studies for the Unites States (Jaffe, 1989; Feldman, 1994; Anselin et al., 1997a). The results for the two spatial units of observation –regions and provinces- are quite similar. GINN has a positive and significant coefficient in both cases. On the other hand expenditures or personnel employed by universities on research is not found to exert a significant influence on patent activity at a spatial level, in contrast to the studies carried out in the United States.

Therefore, the results, without distinguishing sectors, do not provide evidence to support a positive relationship between university research and regional innovation in Spain. However, as has been pointed out, university research will not necessary result in useful knowledge for every industry. The evidence for specific sectors seems to show that university research spillovers are more important in specific fields than is the diffuse effect of university research (Jaffe, 1989; Anselin et al., 1997b).

With the objective of analysing the effects of university research on regional innovative output in depth some specific sectors, on the basis of the available information, have been selected. In the empirical analysis the sectors usually chosen are the pharmaceutical and chemical industry, electric and electronic machinery and apparatus, precision instruments and the manufacture of machinery and metal products (Jaffe, 1989; Acs et al, 1992; Anselin et al., 1997b). These are mainly high and medium technology industries for which it seems reasonable to expect a positive effect of university research on the innovative output of the firms. For the Spanish case the empirical analysis has been made for:

- The chemical industry, including pharmaceutical products
- Electric and electronic machinery and apparatus
- Office equipment and precision instruments
- Machinery and metal products

The specification of the model is again a Cobb-Douglas production function:

$$\log PAT_{ij} = \beta_0 + \beta_1 \log GINN_{ij} + \beta_2 \log UNIV_{ij} + \varepsilon_{ij} \qquad (3)$$

where PAT_{ij} is corporate patents by regions and sectors, $GINN_{ij}$ innovative expenditures, also by regions and sectors and $UNIV_{ij,}$ an indicator of university research, R&D personnel, by regions and relevant to the industries chosen.

The determination of the relevant university research for each of the four sectors is based on the approach of Feldman (1994). As Dosi (1988) points out the specific characteristics for industries of the scientific base are quite stable in different countries and over time. Specifically, with the available information provided by the INE, the links between university research and industry are presented in Table 4.2.

Table 4.2. Correspondence between university research and industries

Industry	**Scientific fields**
Chemicals and Pharmaceuticals	Chemistry (1.3) and medicine, including pharmacy (3.1)
Electric and electronic equipment and apparatus	Electrical and Electronic Engineering (2.2)
Office equipment and Instruments	Maths and computer science (1.1), Physics (1.2), Biology (1.5) and medicine (3)
Machinery and metal products	Technological engineering (2) except civil engineering (2.1) and electrical and electronic engineering (2.2)

In parenthesis, INE code for scientific fields.

The main figures for these sectors are presented in Table 4.3. More than 70 per cent of the industrial patent applications and about 40 per cent of innovation expenditures was made in these sectors. Also, R&D personnel and expenditures in universities in scientific fields relevant to these sectors account for 62.8 per cent and 63.2 per cent of the total R&D expenditures and R&D personnel respectively[1].

Applications for patents in these sectors were made mainly in Madrid and Catalonia. More precisely, Madrid has the maximum value in electronics, office equipment and instruments while Catalonia is the region with the greatest number of patent applications in chemicals, pharmaceuticals and machinery. On the other hand, in the majority of regions, applications for patents in these sectors were very few, being between zero and five patents[2]. However for the period under consideration, and in almost all regions, there was at least one patent application.

Regional differences are also significant for the innovation expenditures of firms.

[1] In the calculation of these percentages, expenditures and personnel on R&D, 15,172.9 million pesetas and 2,707.9 employees, corresponding to basic medicine, have been subtracted to avoid counting them twice.

[2] The values presented in Table 4.3 on patents are not whole numbers. This is due to the fact that the average value for the 1994-1996 period is presented. In addition, the correspondence table used (Verspagen et al., 1994) between the classification of patents and the sectors on certain occasions assigns a percentage of a patent classified according to the CIP to the sector of the ISIC, and not the entire patent.

Again, Catalonia and Madrid concentrate the greater part of innovation expenditures. However, in all the regions firms have devoted resources to innovation, even though, on many occasions, the values were quite small. The expansion process in universities has meant that in almost every region there is, according to INE statistics, R&D university personnel in all the fields. The maximum value for this variable is always for Madrid, while La Rioja, Extremadura, Castilla-La Mancha and The Balaeric Isles have minimum values.

Table 4.3. Patents, innovation expenditures and university research by sectors

Industries	**PAT(1)**	**GINN(2)**	**UNIVG(3)**	**UNIVPE(4)**
Chemicals and Pharmaceuticals	120.6	93,310.7	37,993.3	6,936.9
Electronics	83.6	76,054.8	11,100.6	2,111.5
Office equipment and instruments	110.8	15,602.8	62,226.0	12,372.6
Machinery and metal products	180.9	63,594.8	16,172.6	2,996.4
Total selected (5)	495.9	248,562.8	133,492.4	24,417.4
Total	**699.3**	**677,941.2**	**189,166.3**	**34,330.1**

(1) Average corporate applications for patents in the period 1994-1996, from information provided by the Spanish Office of Patents and Trademarks (OEPM).
(2) Average corporate expenditures on innovation in the years 1994 and 1996, from information provided by the INE in millions of pesetas.
(3) University expenditures on R&D in 1995, INE
(4) University personnel in R&D in 1995, INE.
(5) Expenditures and personnel in R&D for medicine are included both in chemicals and pharmaceuticals and also in office equipment and instruments.

To estimate the model, two complementary possibilities have been used. Firstly, the estimation was carried out by the usual OLS regression. Secondly, and due to the characteristics of the dependent variable, coefficients have been estimated with a Poisson regression[3]. Patents are a typical example of count data. In these cases, where the dependent variable varies, showing zero, small values or large values, a specification like the Poisson regression model which takes in account these characteristics may be preferable to a linear regression model estimated by OLS (Hausman, Hall and Griliches, 1984). The use of Poisson regression models is very common in empirical analyses with data on patents or counts of innovations (Hausman, Hall and Griliches, 1984; Blundell et al., 1995; Baptista and Swann, 1998; Feldman and

[3] In the case of the Poisson regression model, that requires the use of whole numbers, the dependent variable is the total number of patents by Autonomous Community in the 1994-1996 period, adjusting the cases in which the correspondence table used assigns only a percentage of the patent.

Audrestch, 1999).

The results by OLS and by Poisson regression are quite similar, except in the case of chemicals and pharmaceutical products (estimation results in the appendix).

For every sector, except in the case of chemicals and pharmaceuticals in the OLS estimation, innovation expenditures have significant and positive coefficients, with elasticities between 0.2 and 0.5. These results coincide with those obtained for all the sectors and with the existing evidence and show the importance of dedicating resources to obtaining innovations.

In contrast, the results on the influence of university research on innovation output at a spatial level are different for the selected sectors, with statistically significant coefficients only in the electric and electronic sector.

In the case of machinery and metal products there is not enough evidence to support a positive relation between university research and innovative output at a spatial level. With the OLS estimation the coefficient is not statistically significant and with the Poisson regression there is only weak evidence, it being significant only at the 10 per cent level. This sector forms part of the medium technology activities. In this sector, according to the information from the "Encuesta sobre innovación tecnológica" ("Technological Innovation Survey") carried out by the INE (1998), the main sources of innovative ideas are, in the opinion of the firms, internal R&D activities, production activities and clients, while universities are placed in a marginal position as a source of innovative ideas.

In the case of office equipment, computers and instruments neither is there evidence in favour of university research. Again, according to the INE (1998) survey, the main sources of innovations in this sector are clients, production activities, internal R&D activities, and also competitors firms, fairs and exhibitions. Universities, although with a better evaluation than for industry as a whole, are placed in a secondary position.

Thirdly, university research influences innovative output positively in the manufacture of electric and electronic machinery and apparatus. This result, found both with the OLS estimation and with the Poisson regression, shows the importance of proximity for transmitting and capturing knowledge spillovers in this sector. In this industry, and especially in the manufacture of electronic machinery and apparatus, universities are more highly considered as a source of innovative ideas than in the rest of the sectors included in the INE (1998) survey, with the exception of the pharmaceutical industry. Cooperation relations between firms and universities are also quite frequent in this industry.

Finally, the results for the chemical industry, including pharmaceutical products, do not coincide in the OLS estimation and in the Poisson regression. In the OLS estimation, neither the GINN nor the UNIV variables are statistically significant, although they both have the positive sign that was expected. In the Poisson regression the coefficient of innovation expenditures is positive and statistically significant, a result in accordance with the importance that research and development activities in this sector have in finding new products. However, the coefficient of university research is not statistically significant, a result which demands a deeper explanation. The pharmaceutical industry is one of the sectors where basic research carried out in universities is most important as a source of innovative ideas. According to the INE (1998) survey, it is in this sector that university research obtains the best evaluation. For the chemical industry, excluding pharmaceutical products, the points are lower, being very similar to industry as a whole[4]. The importance of university research for the pharmaceutical industry does not necessarily mean that geographical proximity is relevant for the firms participation in the benefits of university research. Together with the importance of basic research, carried out by universities, as a source of innovative ideas, firms cooperate with the universities at various stages (pre-clinical and clinical tests and analysis) of the process of developing a new pharmaceutical product. In the case of basic research relevant information is presented in a codified form –articles, publications- so geographical distance does not have a significant influence. In the other hand in cooperation relations between firms and universities other variables like quality or the specialisation of the university in the subject of research of interest to the firm may have greater importance than geographical proximity. According to interview information with pharmaceutical

[4] Although independent estimations have been carried out for the chemical and pharmaceutical sectors, estimations very affected by the small number of observations, the results obtained did not vary substantially.

firms, more than 50 per cent of the cooperation relations that Spanish firms establish with universities are with foreign universities.

To sum up, the analysis of the influence of university research on innovative output at a spatial level has shown that university research does not, either as a whole or in the selected sectors, exert a positive influence, except in the electronics industry. Some of the main reasons for this result may be the following:

Firstly, as has been pointed out, the growth of universities and the creation of new universities has been very considerable during the last decade. To transmit knowledge and to establish relations between universities and firms needs a period of time (Geuna, 1996). It is very possible then that most of these new universities are in fact exerting a very small influence on the innovative capacity of the territory in which they are placed. However, estimations excluding these universities do not produce changes in the results.

Secondly, according to the INE (1998) surveys, universities have little importance as a source of innovative ideas for firms, and they are evaluated as being, as possible sources, among the last.

Table 4.4. Sources of innovative ideas

Internal R&D activities	2.2
Production	3.4
Marketing	2.4
Competitors	2.8
Clients	3.6
Experts and consulting firms	1.5
Suppliers	2.3
Universities	0.8
Public research institutions	1.0
Research Associations	0.9
Divulgation of patents	0.9
Conferences, meetings and publications	1.7
Trade Fairs and exhibitions	2.9

Source: INE, 1998. Scale from 0, without importance to 5, very important.

Finally, abundant case studies and analyses of the Spanish science and technology system have shown the limited connections between universities and Spanish firms. Specifically underlined have been the lack of links in Spain between the generation of science and the research and development carried out by firms, the limited use made of scientific and technological potential generated by the public R&D system by Spanish firms, and the excessive orientation of public R&D policy towards research in relation to the need for a greater effort in technological development (COTEC, 1998).

In conclusion, the results obtained in the analysis applied suggest the presentation of some brief comments on policies for encouraging innovation in Spain. The contributions of the new theories of economic growth have brought the importance of external economies in economic development to a prominent position. It has also been shown that technological externalities are more relevant in smaller spatial environments. Consequently, the fostering of external economies in an area is a subject of particular interest for action connected with industrial promotion policy (Myro, 1994; Costa, 1996). The presence of a powerful scientific and technological infrastructure favours technological development and is a factor in attracting the location of new innovative activities and consequently positively influences the level of regional growth.

The results have shown that research in universities does not significantly influence the innovative capacity of the firms in their surroundings. Even with all the caution necessary, given the difficulties of being exact about the relation between academic research and entrepreneurial innovation (Griliches, 1992; Blind and Grupp, 1999), this result coincides with diagnoses of the Spanish innovation system (COTEC, 1997, 1998). Therefore, in spite of the remarkable improvements made in scientific research in Spain, as shown by the increase in the share worldwide of Spanish scientific publication (OCYT, 1999), its impact on entrepreneurial innovation is still small. Consequently it seems necessary to reinforce the transfer of the results of research and links between universities and firms. This would be advantageous for both. Nevertheless, as Rosenberg and Nelson (1994) point out, reinforcing the connection between universities and firms should be done whilst respecting the existing division of labour, as objectives are different and research in firms and in universities is the result of different mechanisms and interests.

Appendix: Estimation results. Regions and sectors

	Chemical and Pharmaceutical PAT		Electronics PAT		Office equip. and instruments PAT		Machinery and metal products PAT	
	OLS	Poisson	OLS	Poisson	OLS	Poisson	OLS	Poisson
C	-13.3572 (-2.595)	-21.3360 (-8.224)	-5.9899 (-2.138)	-3.7124 (-2.559)	-9.9290 (-1.970)	-4.4756 (-1.746)	-11.2086 (-3.017)	-12.7429 (-10.087)
GINN	0.1925 (1.028)	0.7798 (10.884)*	0.3468 (6.633)*	0.3786 (5.936)*	0.2171 (2.103)**	0.3319 (8.076)*	0.3769 (3.327)*	0.5139 (13.031)*
UNIV	0.3070 (0.611)	-0.3196 (-1.540)	0.6301 (4.628)*	0.4040 (4.054)*	0.1166 (0.305)	0.3898 (1.633)	0.1968 (1.282)	0.1186 (1.796)**
POB	0.6743 (1.370)	0.9610 (4.026)*	-0.0412 (-0.1868)	-0.0688 (-0.578)	0.5546 (1.216)	0.0476 (0.180)	0.4678 (1.778)	0.5416 (5.487)*
N	17	17	16	16	15	17	17	17
R^2 adj	0.626		0.901		0.634		0.792	
White	5.305		8.892		2.783		7.525	
Log L		-2.370.6		-1.299.4		-1.857.8		-3.432.1
G^2		65.056		28.224		68.495		55.626

t-values in parenthesis.* indicates significance of at least 95%.** indicates significance of at least 90%.

All variables in logarithms. In OLS estimations dependent variable is the log of patents, excluding the observations with zero. For the electronic sector, La Rioja has been excluded due to 0 values for the variable UNIV.

References

Acs, Z., Audrestch, D., Feldman, M. (1992): "Real effects of academic research: comment", *The American Economic Review*, vol 82. n. 1, pp. 363-367.

Anselin, L., Varga, A., Acs, Z. (1997a): "Local geographic spillovers between University research and high technology innovations", *Journal of Urban Economics* n. 42, pp. 422-448.

Anselin, L., Varga, A., Acs, Z. (1997b): *Entrepreneurship, geographic spillovers and University research: a spatial econometric research* Working Paper n. 59, ESRC Centre for Business Research.

Audrestch, D. (1998): "Agglomeration and the location of innovative activity", *Oxford Review of Economic Policy*, vol 14, n 2, pp. 18-29.

Audrestch, D., Feldman, M. (1996): "R&D spillovers and the geography of innovation and production", *The American Economic Review* vol 86, n.º 4, pp. 630-639.

Bania, N., Calkins, L., Dalenberg, D. (1992): "The effects of regional science and technology policy on the geographic distribution of industrial R&D laboratories", *Journal of Regional Science*, vol 32, nº 2, pp. 209-228.

Bania, N., Eberts, R., Fogarty, M. (1993): "Universities and the startup of new companies: Can we generalize from route 128 and Silicon Valley?, *The Review of Economics and Statistics* 75, pp. 761-766.

Baptista, R., Swann, P. (1998): "Do firms in clusters innovate more?, *Research Policy* nº 27, pp. 525-540.

Blind, K., Grupp, H. (1999): "Interdependencies between the science and technology infrastructure and innovation activities in German regions: empirical findings and policy consequences", *Research Policy* nº 28, pp. 451-468.

Blundell, R., Griffith, R., Van Reenen, J., (1993): "Dynamic count data models on technological innovation", *Economic Journal* nº 105, pp. 333-344.

Buesa, M. (1998): *I+D e innovación tecnológica en las regiones españolas*, Documento de Trabajo nº 13, Instituto de Análisis Económico y Financiero, Universidad Complutense, Madrid.

Castells, M. (1992): "Génesis y estructura de los medios de innovación tecnológica industrial: un análisis comparado", *Quaderns de Tecnologia* nº 5, Institut Català de Tecnologia, pp. 7-12.

Costa, M.T., (1996): "Política industrial y desarrollo local", *Revista Asturiana de Economía* nº 5, pp. 27-39.

COTEC (1997): *Informe COTEC. 1997. Tecnología e Innovación en España*, Fundación COTEC para la innovación tecnológica, Madrid.

COTEC (1998): *El sistema español de innovación. Diagnósticos y recomendaciones,* Fundación COTEC para la innovación tecnológica, Madrid.

Dosi, G. (1988): "Sources, procedures and microeconomic effects on innovation", *Journal of Economic Literature* Vol XXVI, septiembre, 1988, pp. 1126-1171.

Feldman, M. (1994): *The Geography of innovation*, Kluwer Academic Publishers. Dordrecht.

Feldman, M. (1999): "The new Economics of innovation, spillovers and agglomeration: a Review of empirical studies", *Economics of Innovation and New Technology*, Vol 8, nº 1 y 2, pp. 5-25.

Feldman, M., Audrestch, D. (1999): "Innovation in cities: Science-based diversity, specialization and localized competition", *European Economic Review*, Vol. 43, nº 2, pp. 409-429.

Florax, R. (1992): *The University: a regional booster? Economic impacts of academic kowledge infrastructure*, Aldershot, Ashgate Publishing.

Freeman, C, (1988): "Japan: a new national system of innovation?" en Dosi et. al. (ed.) *Technical change and Economic theory*, Pinter Publisher, Londres.

Geuna, A. (1996): *European Universities. Relationships among age, dimension and science research quality*, Working Paper MERIT 2/96-003, Maastricht, Holanda.

Glaeser, E., Kallal, H.D, Scheikman, J.A y Shleifer, A (1992): "Growth in cities", *Journal of Political Economy*, vol. 100, n.6, pp. 1.127-1.152.

Griliches, Z. (1979): "Issues in assesing the contribution of research and development to productivity growth", *Bell Journal of Economics*, 1979, 10 (1), pp. 92-116.

Griliches, Z. (1990): "Patent statistics as economic indicators: a survey", *Journal of Economic Literature*, Vol. XXVIII, diciembre, 1990, pp. 1.661-1.707.

Griliches, Z. (1992): The search for R&D spillovers, *Scandinavian Journal of Economics* nº 94, pp. s29-s47.

Hausman, J., Hall, B., Griliches, Z. (1984): "Economic models for count data with an application to the patents-R&D relationship", *Econometrica* nº 52, pp. 909-938

INE (1997): *Estadística sobre actividades en investigación científica y desarrollo tecnológico. 1995,* Instituto Nacional de Estadística, Madrid.

INE (1998): *Encuesta sobre innovación tecnológica en las empresas. 1996.,* Instituto Nacional de Estadística, Madrid.

Jacobs J. (1986): *Las ciudades y la riqueza de las naciones*, Ed. Ariel.

Jaffe, A. (1989): "Real effects of academic research", *The American Economic Review,* vol 79, n. 5, pp. 957-970.

Lundvall, B. (Ed.) (1992): *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, Londres.

Mowery, D. (1995): "The practice of technology policy" en P. Stoneman (Ed.): *Hanbook of the Economics of Innovation and Technological Change*, Blackwell Publishers Ltd.

Myro, R. (1994): "La política industrial activa", *Revista de Economía Aplicada* nº 6 (vol. II) pp. 171-182.

Nelson, R. (1986): "Institutions supporting technical advance in industry", *The American Economic Review* Vol. 76, n 2, pp. 186-189.

Nelson, R. (Ed.) (1993): *National Innovation Systems. A comparative Analysis,* Oxford University Press.

OECD (1992, 1997): *Proposed guidelines for collecting and interpreting technological innovation data. Oslo Manual*, Paris.

OECD (1999): *Main science and technology indicators. 1999-2,* Paris.

OCYT (1999): *Indicadores del sistema español de ciencia y tecnología. 1998,* Oficina de Ciencia y Tecnología, Madrid.

Pavitt, K. (1984): "Sectoral patterns of technological change: Towards a taxonomy and a theory". *Research Policy*, 13, pp. 343-373.

Pavitt, K. (1998): "The social shaping of the national science base", *Research Policy* nº 27, pp. 793-805.

Perrin, J. C. (1992): "La capacitat innovadora de la indústria d'una regió", *Quaderns de Tecnologia* nº 6, Institut Català de Tecnologia, pp. 4-14.

Rosenberg, N. (1976): *Perspectives on Technology,* Cambridge University Press, Cambridge, MA.

Rosenberg, N. (1982): *Inside the black box: Technology and Economics*, Cambridge University Press, Cambridge, MA.

Rosenberg, N.; Nelson, R. (1994): "American universities and technical advance in industry", *Research Policy* n. 23, pp. 323-348.

Saxenian, A. (1994): *Regional advantatge. Culture and competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge, Massachusets.

Sivitanidou, R., Sivitanides, P. (1995): "The intrametropolitan distribution of R&D activities: theory and empirical evidence", *Journal of Regional Science* Vol. 35, n. 3, pp. 391-415.

Varga, A. (1998): "Local academic spillovers and the concentration of economic activity", paper presented in the 38th European Regional Science Association Congress, Vienna, August 1998.

Verspagen, B., Moergastel, T., Slabbers, M. (1994): *MERIT concordance table: IPC-ISIC (rev. 2)*, MERIT, Research Memorandum 2/94-004.

Verspagen, B. (1997): "European regional clubs: Do they exist, and where are they heading? On economic and technological differences between europeans regions", paper presented in the Congress "Economic growth and change: a comparative perspective", Calgary, 19-21, June, 1997.

Von Hippel, E. (1988): *The sources of innovation*, Oxford University Press.