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The location of innovation.Universities and technological infrastructure in Spain

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THE LOCATION OF INNOVATION. UNIVERSITIES AND TECHNOLOGICAL INFRASTRUCTURE IN SPAIN[a,b]

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ABSTRACT: During the last decade, in Spain, there has been important growth and territorial expansion of universities and technological centres in support of the innovative activity in firms. This paper is divided into two parts. Firstly, through a review of the theoretical and empirical studies the main connections between geography and innovation are presented. Secondly, in the framework of a Griliches-Jaffe knowledge production function the relation, at a geographical level, of university research, technological infrastructure and human capital to innovations in Spain is explored.

Key words: geography of innovation, knowledge spillovers, R&D
JEL classification: O30, O18, R30, R58

RESUMEN: En la última década ha tenido lugar en España un crecimiento importante, junto a una expansión territorial, de la universidades y centros de apoyo a la innovación. Este trabajo se divide en dos partes. En primer lugar, se presentan las principales relaciones entre la geografía y la innovación, mediante un repaso a las principales aportaciones teóricas y aplicadas. En segundo lugar, se examina, en el marco de una función de producción de conocimientos tecnológicos Griliches-Jaffe, la relación entre investigación universitaria, infraestructura tecnológica, capital humano e innovaciones en el caso de las provincias españolas.

Palabras clave: Geografía de la innovación, externalidades del conocimiento, I+D.
Códigos JEL: O30, O18, R30, R58

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1. Introduction

> "After all, intellectual breakthoughs must cross hallways and streets more easily than oceans and continents"
>
> *Glaeser, Kallal, Scheinkman y Shleifer, 1992.*

The relation between innovative activities and geography is a subject of growing interest in economics. The empirical studies have confirmed the importance of geographical proximity in the transmission of knowledge (Jaffe et al., 1993) and have shown that some regions have advantages in their ability for generating innovations. Then, as Jaffe y Henderson (1999) point out the study of how the differences in the structure and regional resources is a relevant focus in analysing technological change.

In this article the results of an empirical analysis on innovation and geography in Spain are presented. As Feldman (1999) points out, there are two main lines of empirical economic analysis about innovation and location. In the first, the geographical dimension is one of the determinants of the location and the influence of geographical proximity over the transmission and capture of knowledge spillovers is examined. This research is based on the production function with an indicator of the innovation as a dependent variable and a relation of potential explanatory variables, all of them for the same geographical area. In the second one the growth level and productivity of the regions are examined. In this case an indicator of the innovation level is used as an explanatory variable with the study of its effects on regional economic performance.

The empirical analysis that is presented in this article forms part of the first approach. With the knowledge production function defined by Griliches (1979, 1990) and modified by Jaffe (1989) to include the geographical dimension, the effects that location of some knowledge sources have on innovation performance in small geographical areas are examined. Specifically, three possible sources of external knowledge economies are included. These are human capital, universities and technological innovation support centres. The empirical analysis is specially focused on the latter two which have experienced substantial development in Spain since mid eighties. This effort to expand has been justified, frequently, by the expected positive impact on innovation ability and growth of the regions in which these institutions are placed.

This article is organised as follows. First, the main characteristics of the knowledge production function and the methodological approach and the results of the most relevant applied research (Jaffe, 1989; Acs et al., 1992; Feldman, 1994; Anselin et al., 1997a; Blind and Grupp, 1999) on this subject are examined. Secondly, some economic and statistical considerations about the empirical analysis done for of the Spanish case are presented. About this it is remarkable the use of small sized geographical units, the Spanish provinces, the presentation of various functional forms for the model and the incorporation of spatial econometric techniques in the estimations. Finally, the results obtained in the estimations are presented and examined. Briefly, these results show the importance that the presence in a territory of infrastructures to support innovation have for business innovative output. However, in opposition to the results obtained in research done in the United States and Germany, there is no evidence to support a positive relation between university research and regional innovation. With these results some technological and industrial policy proposals are presented.

2. Theoretial framework and empirical studies

The usual theoretical framework in the economic literature for the econometric analysis of innovative processes and technological spillovers from R&D activities is based on the production knowledge 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).

Accepting Griliches proposal, R&D expenditures are the main input to generate innovations. Formally:

$$K = f(R)$$

where K is the new economically valuable knowledge and R the resources for research. Departing from this model a large number of empirical studies have been carried out with the purpose of studying the relation between K and R. Obviously, K , the output of innovative and research activities is not directly observable and then it is necessary to use some indicator of K. Patents have been the most usual indicator in economic literature. As Griliches (1990) points out the hypothesis is that some random fraction of K is patented. The elaboration of this model implies some important simplifications in the definition of the variables and about their relations. Also this model must be considered as a statistical descriptive model and not as a formal theory of patents, because a formal theory would have to explain the economic and legal conditions why the benefits of patenting would be greater than the application costs and the consequences that revealing the elements that constituted this technology imply (Griliches, 1990).

Jaffe (1989), with the objective of analysing the importance of geographical proximity in the capture and transmission of technological externalities modifies the knowledge production proposed by Griliches and introduces spatial dimension and university research. Then, the unit of observation is not the firm but a spatial area (Audrestch, 1998). The model proposed by Jaffe is a Cobb-Douglas production function with two inputs:

$$\log PAT_i = \beta_1 \log GID_i + \beta_2 \log UNIV_i + \varepsilon_i \qquad (1)$$

where PAT_i are private patents in the state "i", GID_i and $UNIV_i$ the R&D expenditures of firms and universities in the same state "i". The hypothesis that Jaffe proposes is that a positive influence of university research in an state on the patents of the same state show the existence of geographically mediated spillovers, of some kind of technological externality without distinguishing the mode of technological transference.

Therefore, in this model, geography matters in innovative activities. Contrary to the approach that new knowledge is a public good that is easily accessible and has very few transmission costs, there is empirical evidence that 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). As Pavitt (1998) states: “the links between basic research and technological practice are geographically constrained”.

The production function presented before, known in the literature as the modified knowledge production function Griliches-Jaffe, has been the basis for some empirical studies. The most noteworthy are Acs et al. (1992), Feldman (1994), Anselin et al. (1997a; 1997b) and Blind and Grupp (1999), which all have the objective of analysing geographical local spillovers and the determinants of the location of innovative output. Nevertheless, this production function may be considered an empirical model, because from a theoretical viewpoint, there is no a specific framework to study the existence of local spillovers or to analyse the regional distribution of innovative activities.

The first study (Acs et al., 1992) reproduces Jaffe’s (1989) analyses with the use of a direct indicator of new technological knowledge instead of patents. This indicator is the number of innovations introduced in 1982, elaborated by the “US Small Business Administration” with the information of the main technological and engineering magazines. Their results are similar to those obtained by Jaffe. In both cases the estimations reveal that university research done in a state positively influences innovative output, patents or the number of innovations in the same state.

Feldman (1994) deepens in the analysis of the geography of innovation and introduces new variables. Her purpose is to analyse, among other questions, the relevance of technological infrastructure to innovative regional output and the determinant factors of innovative regional capacity. This complements the previous analysis of Jaffe (1989) and Acs et al. (1992), because the generation of spillovers may have its origin not only in university research but also in related firms or service networks to firms. Specifically, Feldman considers that geographical innovations may benefit from of spillovers from other firms with similar technologies or from support institutes that provide services to the firms in this territory. Nevertheless there is no model of the way in which spillovers are transmitted. Then the term spillover is used by Feldman in a broad sense because not all the interactions between innovative inputs and output are true spillovers. In her model, the innovative output is related to four possible inputs:

$$\log INN_i = \beta_1 \log GID_i + \beta_2 \log UNIV_i + \beta_3 \log SERV_i + \beta_4 \log REL_i + \varepsilon_i \qquad (2)$$

with INN_i is the number of innovations in the state i in the sectors for which is information, GID_i and $UNIV_i$ as in the previous case, and REL_i and $SERV_i$ are the presence of related industries and services to the firms respectively. The estimations show that all the variables are statistically significant. Then, innovative regional output is positively related to innovative inputs (Feldman, 1994).

With the same purpose Blind and Grupp (1999) examine the interdependencies between academic and technological infrastructure and innovative output for two German regions, Baden-Wuerttemberg and North Rhine Westphalia. Their model is similar to Feldman's introducing two indicators of technological infrastructure together with university research. The main novelty is that they distinguish between basic research technological centres oriented from centres oriented mainly to applied research with strong financial support from their respective regional government. The results show that university activities have a positive impact on corporate patents. Also, the existence of applied research centres contributes to innovation capacity, especially in the case of de Baden-Wuerttemberg. On the other hand the indicator of basic research centres is not significant in any estimation.

Anselin et al. (1997a, 1997b) introduce new variables and use a smaller territorial level, the US metropolitan areas (MSA), which are a preferable area to analyse the location of innovative activities. With this they overcome the limitations of the use of the States as an spatial analysis unity, because as Krugman (1991) points out "States are not really the right geographical units" while Audrestch (1998) precises "the relevant geographic unit of observation is at the city level". They also use econometric spatial techniques needed to overcome the problems of spatial dependence that regional cross data often present. Specifically they use a spatial econometric approach with tests to examine the existence of spatial effects and in the needed cases they use estimation procedures with the introduction of this effects. The tests (Anselin et al. 1997a) show the presence of spatial autocorrelation where the spatial dependence is in the error term. Also, the use of spatial lagged exogenous variables make possible to examine in a more accurate way the geographic dimension of the research spillovers. The results obtained by Anselin et al.

(1997a, 1997b) reinforce the conclusions of the previous studies and underline the importance of using spatial econometric techniques in the estimations.

3. Empirical analysis for Spain. Model and results

The purpose of the model considered is to examine the explanatory factors of the location of innovative output. The main objective is to analyse, first, if university research and technological support centres in a specific geographical unit are explanatory and significant variables of innovative corporate output of the same geographical area. Also, as a complementary analysis, another purpose is to examine if the presence of human capital in an area positively influences innovative output. These three variables are key factors generating new economic knowledge (Audrestch, 1998).

The models are based, as in the studies previously examined, in the knowledge production function proposed by Griliches (1979, 1990), where innovative output are in function of innovative inputs To choose this theoretical framework is not, of course, free from criticisms. Nevertheless as Stoneman (1995) has pointed out “Griliches’ implicit theoretical framework is neo-classical, centring around the production function concept. Pavitt and Patel… have already queried the relevance of such an approach. However as in all exciting areas there are a multiplicity of theoretical approaches with little universal agreement as to the superiority of one over another. It is often the case that the choice of the framework is a matter of “horses for courses” and the most appropriate framework depends crucially on the questions being asked”.

Specifically, the models are:

$$INNOV_i = f\,(GINN_i, UNIV_i, STMA_i,) \qquad (3)$$

$$INNOV_i = f\,(GINN_i, KHSUP_i) \qquad (4)$$

where $INNOV_i$ is an indicator of innovations – corporate patents (PAT_i) – of a geographical area, $GINN_i$ is an indicator of the private resources on innovation, $UNIV_i$ is the university research, $STMA_i$ is an indicator of technological and scientific centres excluding universities, and $KHSUP_i$ human capital. These variables have to influence positively on the innovation regional potential with the common hypothesis (Capron, 1992):

$$(\partial f / \partial GINN), (\partial f / \partial UNIV), (\partial f / \partial STMA), (\partial f / \partial KHSUP) > 0$$

The geographical unit of analysis is the province (NUTS-3). The determination of the right unit is a controversial subject. The statistical constraints have led to the use of geographical units greater than theoretically preferable. Most studies agree that the preferable units are cities or metropolitan areas because it is in these where takes place usually the interaction and knowledge exchange between different agents. In the Spanish case statistical constraints make the use of cities or metropolitan areas as unit analysis impossible. However, provinces are a better option than the usual unit, regions or autonomous communities (NUTS 2). Therefore a data base with information for provinces has been constructed in order to analyse the effects of geographical proximity on innovation.

To measure innovative output of firms there is only one possibility which is to use corporate applications for patents (PAT). Applications for patents may be made in different ways. Because the objective it is to analyse the regional distribution of patents the total number of resident patent applications[1] via national, European or other international treaty (PCT) has been used. In this case the only way to establish the location of the patent is the province of residence of the applicant[2]. This indicator, despite its deficiencies, has been the most common in economic literature.

On the other hand, the only available information, on request from the National Institute of Statistics (INE), to measure the effort of firms and universities in provinces is expenditures on innovation (GINN) as a measure for firms, and R&D personnel (full-

[1] Specifically, it is not the first application which has been used but those where the complete information is available and at the disposal of the public. Under Spanish law, a period of 18 months is required from the application data.

[2] The regional distribution of patents classified by the residence of the applicant or by the residence of the inventor is, in Spain, very similar. According to information compiled by the Spanish Office of Patents on applications for European patents made by residents in Spain in the period 1978-1997, the correlation index between these two variables was 0.999 (Sanz and Arias, 1998).

time equivalent) as an indicator of university research (UNIV). 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. The determination of location for this variable does not present the common problem of the distinction between headquarters, R&D labs and production plants. In its survey, the INE asks the firms to distribute their expenditure on R&D or innovation into the various regions where they have carried out this kind of activity. Therefore the territorial distribution of this variable corresponds to the actual location where these activities have been carried out. For the other two variables (STMA and KHSUP), as it is presented in the appendix, the source are specific studies[3].

To estimate these models some functional forms have been used. It is not easy to define the relation and interaction mode between the variables chosen with precision. Furthermore the current theoretical framework does not allow the functional form to be determined. As has been explained, the knowledge production function may be considered as a statistical descriptive model (Griliches, 1990). Also the models used in the previous studies are mainly empirical models with the election of a Cobb-Douglas production function for reasons of simplicity. In spite that applied innovation studies with the use of production functions seem to show that more complex formulations do not improve estimation results (Capron, 1992), it seems interesting to use different functional forms[4] and to try to show the consistency of the obtained results.

In this research, a Cobb-Douglas production function has been used firstly. This is the functional form used in the studies previously described, as models (1) and (2), and it is very frequently used in the impact analysis of R&D activities and in the effects of public R&D (Capron, 1992). Then, the functions used are:

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[3] Simple statistics of the variables and sources are presented in the appendix.

[4] To select the functional form is a common problem in empirical studies on the relation between R&D and patents. Pakes and Griliches (1984) start their research with an analysis of different functional forms. Departing from a production function they examine different possibilities of establishing the appropriate relation. Finally they choose a variant of the Box-Cox transformation, the logarithmic transformation.

$$\log PAT_i = \beta_0 + \beta_1 \log GINN_i + \beta_2 \log UNIV_i + \beta_3 \log STMA_i + \varepsilon_i \qquad (5)$$

$$\log PAT_i = \beta_0 + \beta_1 \log GINN_i + \beta_2 \log KHSUP_i + \varepsilon_i \qquad (6)$$

The use of a Cobb-Douglas production function, apart from the restrictions of the hypothesis that are part of, limits the incorporation of the observations with zero values in the explanatory variables, which is a common problem in the empirical research on this subject. To eliminate these cases means to truncate the sample (Pakes y Griliches, 1984) and to reduce its representativity. For instance, to cut out the provinces that do not have technological centres or universities means a loss of information because it would be interesting to analyse the innovative output of the provinces of this kind. A useful alternative when theoretical hypotheses do not allow the determination of the correct functional form is the well-known Box-Cox transformation (Spitzer, 1982). The Box-Cox transformation consists in:

$$f^{(\lambda)}(x) = (x^{\lambda} - 1) / \lambda \qquad \lambda \neq 0$$

$$f^{(\lambda)}(x) = \ln x \qquad \lambda = 0$$

which for the model (5) considered it leads to:

$$PAT_i^{(\lambda)} = \beta_0 + \beta_1 GINN_i^{(\lambda)} + \beta_2 UNIV_i^{(\lambda)} + \beta_3 STMA_i^{(\lambda)} + \varepsilon_i \qquad (7)$$

With this transformation the parameter λ, which also has to be estimated, dictates the functional form (Spitzer, 1982). The Box-Cox transformation has been used in the empirical analysis of R&D activities (Levy, 1990) and permits the introduction of the cases with zero value in the observations (Caves et al., 1980).

As a complementary possibility, the results of the estimations where university research and technological centres are introduced on the efficiency parameter of provincial innovation expenditures are presented. The main way in which universities and technological centres influence the innovative output of a province are with the interaction with the efforts of innovative firms. University research and technological centres increase, through knowledge transmission, technological opportunities and productivity and the efficiency of R&D firms activities, while to a lesser degree they generate new technologies (Nelson, 1986).

Antonelli (1995) introduces, in the production function, technological externalities as a general increase of efficiency. Specifically, two possibilities are considered:

$A = f\ (IKSTOCK)$ and $A = f\ (N)$

In the first case, to analyse the relations between productivity and technological change due to the diffusion of information and communication new technologies, it is assumed that global efficiency depends on capital stock in information and communication technologies, IKSTOCK. The second case is devoted to network analysis, examining the advantages of spatial proximity for transmitting and capturing technological externalities. Then A depends on the number of firms, N, with which a specific firm may develop information interchange and complementarities in the generation and adoption of new technologies.

With a similar approach, the efficiency of innovative firm activities will be affected by the possibility of having relations with universities and technological centres surrounding the firm. The functional form is defined as:

$PAT_i = A\ (GINN_i)$

where A represents specific provincial differences in the productivity of the innovative efforts of firms. These differences will depend on the presence in the province of research and technological infrastructure facilities:

$A_i = f\ (UNIV_i,\ STMA_i)$

For estimation purposes, it is assumed that A is:

$A = \exp\ (\beta_0 + \beta_1 UNIVi + \beta_2 STMAi)$

The final model, after logarithmic transformation is:

$$\log PAT_i = \beta_0 + \beta_1 \, UNIV_i + \beta_2 \, STMA_i + \beta_3 \log GINN_i + \varepsilon_i \tag{8}$$

Thirdly, the use of cross data for spatial units requires, as Anselin et al. (1997a; 1997b) point the examination of whether the distribution of the variables is merely random or responds to a pattern of spatial dependence. In regression models, spatial dependence may exist due to the existence of a spatial correlation of dependent or exogenous observations, or because there is spatial dependence across error terms. A general specification of a spatial model is:

$$y = \rho Wy + X\beta_1 + WR\beta_2 + \varepsilon$$
$$\varepsilon = \lambda W\varepsilon + \zeta$$

where y is a vector of n observations of the dependent variable, W is the contacts matrix of order $n{\cdot}n$, X is a matrix of exogenous variables; R a matrix of the spatial lagged exogenous variables; β_1 y β_2 the vectors of the estimated parameters; ρ the spatial autocorrelation coefficient and, finally, ε is the vector of error terms with an spatial dependence autoregressive structure.

The use of spatial econometrics in the estimations allows, as has been pointed out, the problems which have their origin in the spatial dependence of contiguous cross-data observations to be overcome. Furthermore, in the event that there is spatial dependence incorporating these effects allows a deeper understanding of the relation between the variables in space. For instance, in the model presented the value of ρ would show the influence that province innovative output have on contiguous provinces innovative ability.

The results for the functional forms proposed are presented in Table 1. In the first three columns the results are shown using a Cobb-Douglas production function, the fourth column shows the results with the Box-Cox transformation, and the last column with the approach based on the Antonelli (1995) proposal. With the Box-Cox transformation it is necessary to estimate the parameter λ. In order to do this the iterative ordinary least squares method has been used. Examining the value λ, in the rank –2 and +2, which minimises the error sum of squares (Spitzer, 1982), the maximum likelihood estimation of λ is 0.36. Standard errors of estimated parameters have been calculated using the Berndt et al. (1974) estimator, because those obtained directly by OLS are an underestimation of the correct standard errors. In all the cases, population (POP) is introduced as a control variable (Jaffe, 1989), because of differences in the size of provinces.

Table 1. Results of the estimations

Models	5a	5b	6	7	8
	PAT	PAT	PAT	PAT	PAT
C	-14.7342 (-4.791)	-11.2650 (-4.353)	-15.1516 (-10.721)	-8.2173 (-2.197)	-13.1264 (-5.908)
GINN	0.4883 (5.243)*	0.4212 (3.183)*	0.4772 (5.748)*	0.4117 (4.617)*	0.4483 (5.046)*
UNIV	0.0434 (0.207)			0.0193 (1.098)	-0.0000 (-0.153)
STMA		0.3863 (2.569)*		0.0430 (2.091)*	0.0022 (1.944)**
KHSUP			0.6304 (1.834)**		
POP	0.656 (2.077)*	0.3836 (1.606)	0.6295 (4.866)*	0.2262 (0.855)	0.5872 (3.408)*
N	41	21	50	50	50
R^2 aj.	0.713	0.787	0.791	0.801	0.790
White	5.832	2.334	5.070	5.134	6.013
LM-LAG			7.625 (1)	8.553 (1)	7.660 (1)
LM-ERR			4.279 (1)	5.168 (1)	6.436 (1)

Values of t statistic between parentheses. *Indicates significance of at least 95%.**Indicates significance of at least 90%.

(1). Rejection of null hypothesis of random spatial distribution with a 0,05 significance level.

For all the estimations the White test has been used to detect heteroscedasticity. The values are presented with the estimations and allow the existence of heteroscedasticity to be rejected.

The results show that all the variables have the expected positive sign. Furthermore, GINN, STMA y KHSUP present statistically significant coefficients as explanatory variables of innovative output. However, university research is not significant in any estimation.

Before analysing the results in detail it is necessary, as has been pointed out, to examine the possible existence of spatial dependence because to not do so would have relevant consequences for the results of the estimations. To examine the presence of spatial dependence and to use spatial econometric techniques it is necessary to specify a contact or a spatial weight matrix, W, for which different forms have been proposed in the literature. In this case, and because the objective is to examine the importance of geographic proximity, a binary contiguity matrix is used. In this matrix, the provinces with common border take the value 1 and 0 otherwise. This matrix is the most commonly used in the empirical literature.

After defining the spatial weight matrix, the presence of spatial dependence was tested with the statistics, LM-ERR y LM-LAG (table 1), which are based on the Lagrange multipliers principle (Anselin, 1988; Florax, 1992). Following the criteria suggested by Florax (1992), as the LM-LAG value is greater than the LM-ERR, the spatial autoregressive model has been selected. The results are presented in Table 2.

Table 2. Results of the estimations. Spatial autoregressive model (spatial lag for the dependent variable)

Models	6’	7’	8’
	PAT	PAT	PAT
W_PAT	0.0629 (2.765)*	0.0637 (2.853)*	0.0638 (2.787)*
C	-16.7143 (-12.201)	-10.5928 (-3.484)	-14.5067 (-7.293)
GINN	0.3959 (5.237)*	0.3309 (4.182)*	0.3642 (4.557)*
UNIV		0.0155 (1.139)	0.0000 (0.3111)
STMA		0.0412 (2.412)*	0.0017 (1.734)**
KHSUP	0.5288 (1.737)**		
POP	0.8227 (6.012)*	0.4716 (2.027)*	0.7548 (4.835)*
Nº	50	50	50
LIK	-41.414	-39.354	-40.998
AIC	92.828	90.708	93.995
Spatial Breusch-Pagan	2.244	1.961	2.760
LM-ERR	0.102	0.086	0.549

Values of t statistic between parentheses. *Indicates significance of at least 95%.**Indicates significance of at least 90%.

The maximum likelihood estimations of the spatial lag model reinforce the previous results. For all the regressions, expenditures on innovation have positive and statistically significant coefficients. Also, the elasticity is quite similar to that obtained in other studies, between 0.3 and 0.6 (Jaffe, 1989; Acs et al., 1992; Anselin et al., 1997a).

Nevertheless, the concern of this applied analysis is centred on the other three variables, UNIV, STMA y KHSUP which are representative of sources generating knowledge. The results for these variables are quite different. Firstly, the existence of technological centres positively affects provincial innovative output. This result is in agreement with abundant empirical evidence, supported by case studies with show the importance of proximity to firms for the efficiency of these technological centres (OCDE, 1992; Pyke, 1994; Costa and García Quevedo, 1996; Mas and Cubel, 1997). Therefore, the existence of technological institutes positively influences the innovative ability of surrounding firms through provision of services, R&D activities, technology transfer and training activities.

Secondly, human capital, measured as the percentage of employees with higher education over the total number of employees is also a significant variable. This result coincides with another analysis on regional innovation capacity done for the Spanish case (Gumbau, 1996). A higher level of education leads to a higher ability to assimilate and to use technological information. The level of education level has a positive influence on learning ability and efficiency, with positive effects in the ability to develop innovations and to use existing innovation.

Thirdly, the results for university research show that while the sign is positive as expected, it is not statistically significant in any estimation. Although empirical evidence is not conclusive with regard to the influence of university on territorial innovation (Anselin et al., 1997a), most of the studies carried out in United States obtain a positive and a significant relation between university research and corporate innovative output at a State and metropolitan level (Jaffe, 1989; Acs et al., 1992; Feldman, 1994; Anselin et al., 1997a).

Finally, including spatial effects allows the conclusion to be drawn that provincial innovative output is affected positively by the innovative activity of neighbouring provinces. Nevertheless the effects are, as is shown by the estimated value of the parameter, very small. Furthermore, estimations with spatial lags for the independent variables have been carried out without obtaining significant parameters. Although the results provide some evidence in favour of the presence of interprovincial spillovers, this evidence is very weak and, in any case their dimension is very small.

To summarise, in all cases the results have shown the different role that universities and technological centres are playing in supporting the innovative capacity of Spanish provinces. While Universities do not positively affect provincial innovative output, the presence of technological centres is a significant variable. Some of the main reasons for this result about universities may be the following:

Firstly, a considerable number of new universities have been created considerable during the last decade. It is very possible that most of these new universities are in fact exerting very little influence on the innovative capacity of the territory in which they are placed because the establishment of relations between universities and firms needs a certain period of time (Geuna, 1996). However, estimations excluding these universities produces the same results.

Secondly, the sources of innovative ideas are not the same in all sectors (Pavitt, 1984). University research is particularly relevant in the so-called science based sectors like drugs or electronics. The small presence of these sectors in Spanish industry (Sánchez y Chaminade, 1998), compared with the European Union and the United States also explains the weak role of the universities as a source of useful knowledge for the surroundings firms.

Finally, 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. Specifically, on a scale from 0, without importance, to 5, very important, they are placed at 0.8. This is very far from the 3.6 obtained by clients as the main important source. This result coincides with abundant case studies and analyses of the Spanish science and technology system that have shown the limited connections between universities and Spanish firms. Specially underlined have been the lack of links in Spain between the generation of science and the research and development carried out by firms and the limited use made by them of scientific and technological potential generated by the public R&D system (COTEC, 1998).

Some brief comments, based on the results obtained, on policies for encouraging innovation in Spain can be made. New theories of economic growth have brought the importance of external economies to economic development into a prominent position. It has also been shown that technological externalities are more important in smaller spatial environments. 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 (Myro, 1994; Costa, 1996).

The results of the empirical analysis have shown, in the first place, that the existence of technological centres contributes positively to the innovative performance of regions. This result coincides with some case studies for some Spanish regions (Barceló, 1993; Buesa, 1996; Costa y García Quevedo, 1996; Mas, 1996) that have shown the positive effects these centres have on the adoption and development of innovations by surrounding firms. However, an exhaustive report on the Spanish system of innovation (COTEC, 1998), points out that the degree of development of these infrastructures is below that of other European Union countries. Therefore, the creation of technological centres, forming part of a coordinated network of private and public institutions, may be considered as a priority line of action in supporting the research and technological development of private firms.

Finally, the results have shown that research in universities does not significantly influence the innovative capacity of the firms in their surroundings. This result coincides with diagnoses of the Spanish innovation system (COTEC, 1998). Therefore, despite of the remarkable improvements made in scientific research in Spain, as shown by increasing Spanish participation in world-wide 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.

Appendix : Variables and sources

	Mean	Std Dv	Maximum	Minimum
PAT	14,41	35,89	199	0,33
GINN(1)	14.144,3	37.788,6	211.247,9	70,5
UNIV	553,32	1.021,74	6.052,4	0
STMA	57,34	115,91	443	0
KHSUP	8,01	2,20	14,99	3,52
POP	779.122,16	931.996,87	5.011.519	92.835

(1) Millions of pta.

- Patents (PAT): annual average of the applications for corporate patents by provinces, 1994-1996. Source: own elaboration with information from the Oficina Española de Patentes y Marcas (OEPM)
- Innovation (GINN): average expenditure of firms on innovation by provinces in 1994 and 1996. Source: National Institute of Statistics (INE).
- University researchers (UNIV): university personnel in R&D (full-time equivalent) by provinces, 1995. Source: Own elaboration with information provided by the INE.
- Technological centres (STMA): technical personnel by provinces in 1995. Source: Fernández de Lucio et al. (1996) "Estructuras de interfaz en el Sistema Español de Innovación. Su papel en la difusión de tecnología"
- Human capital (KHSUP): percentage of the employed population with higher education. 1994-1996. Fuente: Pérez y Serrano (1998) "Capital humano, crecimiento económico y desarrollo regional en España (1964-1997), Fundación Bancaja".

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