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WHAT FACTORS DETERMINE THE GENERATION OF PATENTS IN ANDALUCIA (SPAIN)? DOES PUBLIC POLICY SUPPORT TECHNOLOGICAL KNOWLEDGE GENERATION IN UNIVERSITIES?

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Abstract

The new literature on the National and Regional Systems of Innovation, based on the approaches of the evolutionary economy, attributes an important role to the various different institutions that intervene in the complex processes of innovation. In this context, the Universities have a transcendental role in the Knowledge-based Society; they not only lead scientific research which, in the long term, will determine the technological boundaries of industry, but they also generate scientific knowledge that is directly applicable in the productive processes of industry and commerce. In this study we intend to deal with this latter question. For this, we shall make use of patents as a reliable indicator of technology transfer. Unlike previous studies on university patents, which have utilised universities or university teachers as the unit of analysis in the production of patents, in this study we utilise the research group, as an intermediate unit between the university and the academic inventor or innovator. This option is realistic in so far as the majority of researchers work together as members of a permanent group on a common line of research. With a sample of 1155 Research Groups in the 10 universities of Andalusia, the questions investigated are the following:

How do the human resources (academics with doctorates, graduates and support personnel) influence the generation of patents by universities?

What is the influence of the scientific capabilities of the research group on the generation of university patents?

What influence does external financing, public and private, have on the output of patents?

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1. Introduction

The new literature on national/regional systems of innovation (Freeman, 1988; Nelson, 1993; Lundvall, 1992; Braczyk et al, 1998; Cooke et al 1998) based on the approaches of the evolutionary economy initially postulated by Nelson and Winter (1982), attributes a substantial role to the different institutions that intervene in this complex process and, above all, to the organizational aspects. University, company and government are identified as principal elements of the system of innovation. In a similar line, the thesis of the Triple Helix model (Etzkowitz and Leydesdorff, 1997; 2000; Leydesdorff, 2000) establishes that the university can play an essential role in the process of innovation, and thus strengthen knowledge-based societies. In this modern conception, the universities perform three essential functions as elements of a system of innovation (Schartinger et al. 2002, Smith, 1995): first, they lead the general process of scientific research that has a long term effect on the technological frontiers of industry; second, they generate a type of knowledge that is directly applicable to industrial production processes; third, they provide the principal inputs of the process of industrial innovation: the specialized human resources employed by industry, or the researchers working in those institutions that collaborate with the private industrial sector.

Our objective in this paper is to explore in detail the second of these functions using patents as indicator. Several research studies have demonstrated that the analysis of patents is a sufficiently valid and objective method for determining technology transfer (Archibugi, 1992, Basberg, 1987, Boitani and Ciciotti, 1990, and Trajtenberg, 1990). For Meyer- Krahmer and Schmoch (1998) patents show the interest in commercial exploitation of a new technology (...) A high share of patents on the part of scientific institutions can be considered a good indicator for a close relationship of science and industrial laboratories in the technology field". Also the accessibility of patents allows a more comprehensive treatment than surveys or case studies (Henderson et al., 1998).

Unlike previous studies on university patents that have taken, as the unit of analysis in the production of patents, either the university (Henderson et al. 1998; Coupe 2003), or university teachers (Agrawal and Henderson, 2002), in this study we utilise the research group, considered as an intermediate unit between the university and the academic inventor or innovator. This is a realistic option considering that the majority of researchers are integrated as members of a group following a common line of research; these groups are also the basic unit for regional financing of academic research. With a sample of 1155 Research Groups from 10 Spanish universities, the questions to investigate are the following:

How do the human resources (academics with doctorates, graduates and support personnel) influence the generation of university patents?
What is the influence of the scientific capabilities of the research group on the generation of university patents?
What influence does external financing, public and private, have on the output of patents?

Our working proposal for the article is as follows. First we carry out a review of the literature on the production of technological knowledge in the universities, as measured by patents, and then we put forward the initial working hypotheses, the methodology and the data utilised. Next we present the results of testing our hypotheses. Finally we draw the principal conclusions.

2. Previous literature and hypotheses

While there is a broad literature that has confirmed the significant effects of universities on the economy, there are relatively few studies concerned with the causes underlying the generation of technological knowledge in universities, and its transfer into the productive economy. Recent research work of a quantitative nature has been centered on the technological results exploited commercially by the universities; such research has been quantified by means of licences (Thursby et al, 2001, Thursby and Thursby ,2002, 2003;, Thursby and Kemp, 2002; Friedman and Silberman, 2003). Some of the factors that influence the technology transfer between universities and companies have been demonstrated in these studies; for example, the quality of the centers in which the technology has been developed; the personnel of the University offices of technology transfer; the tradition existing in these institutions of undertaking this type of activity; the resources provided by the government; and location. The literature focusing on the causes underlying the contribution of universities to technology development and transfer utilising patents as the indicator is scarce. One of the more relevant studies is that of Henderson et al. (1998), who compare the university patents of the US during the period 1965-1988; their results show that universities tend to be more interested in medical and pharmaceutical technology and less in mechanical technology. Their analysis of quality suggests that, for recent periods, there does not appear to be any difference of quality between university patents and those granted to other types of organization. In respect of the explanatory causes of the evolution of university patents, they emphasize three essential aspects: the legal framework, or changes in the federal laws that facilitate patent applications by universities (Mowery et al., 2001 put this finding in doubt), increases in industrial funds destined to supporting university research, and the increase in the numbers of interface centers and institutions. Coupé (2003) has estimated a production function for university patents by means of empirical counting models, in which the principal explanatory factors are the academic expenditures on R&D, and the institutional factors considered previously by Henderson et al. (1998). The results of this study confirm the evidence on the institutional effects, in addition to the significant influence of expenditure on R&D on the output of university patents. Miyata (2000) empirically analyzes how North American universities generate results with the potential for early commercial exploitation, and what are the factors that determine these results, using regression models. As the endogenous variable, this author utilizes the number of inventions (although the results are not presented, according to the author, the number of patents or licenses lead to the same results), and as explanatory factors, the funds provided by industry, whether there is a tradition of relationship between the university and the particular industry, the quality of the research, and its relationship with the administration. Using a transversal sample of 69 American universities, the results of the regressions performed indicate that, of the explanatory variables considered, only the quality of the research and the existence of a traditional relationship with the industry, lead to the generation of significant inventions. Owen-Smith and Powell (2003) analyze the sources of North American universities' capacities for generating results with the potential for early exploitation. As possible explanatory causes of the mechanisms by which universities develop patents, these authors suggest know-how (the accumulation of previous patents or experience in the particular field), the personnel dedicated to technology transfer, and contractual links with companies that patent. Their model takes as endogenous variable the number of citations gained by a university patent in the life sciences sector (in other words, the sum of the citations in respect of patents assigned to a university, as a measure of the impact of the organization); the explanatory factors include several control variables (the presence of a Faculty of Medicine, the type of university - public or private -, localization), experience (number of previous patents), scientific capacity (number of articles), scientific impact and capacity for integration in networks. These authors find a positive and significant effect of the size of the portfolio of patents on the number of citations, of the degree of association or integration in networks and of the scientific publications (the academic publications are directly related to a high impact of university patents).

Based on the previous literature, we aim to test the following hypotheses:

H1: The more human resources, in numbers and qualification, deployed by the research group, the more patents are generated.

The human resources constitute an essential variable to be included in the analysis of any function of technological knowledge generation; also, in our case, the deployment of human resources represents a vitally important parameter because in Andalusia the Regional Government considers the number of researchers when awarding public financing to research groups for their interannual activities. The involvement of a larger number of researchers means that a group can obtain more public financing from the regional government.

Thus considering this question, this first hypothesis will enable us additionally to check the goodness of one part of the financing of research groups as a valid factor influencing the generation of technological knowledge.

H2: The scientific capabilities of the research group are an item that positively influences the generation of technological knowledge. This assumes that the capabilities of the group are reflected by the number of researchers deployed.

This hypothesis, supported by the previous empirical work of Miyata (2000), Owen-Smith and Powell (2003) and Schartinger et al. (2002), is also related, in the case that concerns us, with the regional financing of the research groups; therefore we will be able to check, the goodness of part of the regional policy for research in terms of the generation of technological knowledge.

Additionally, the generic formulation of this hypothesis will enable us to introduce many finer points into the model, since the scientific capabilities of the group is a variable that can be measured by several different indicators, as will be made more specific when the variables to be included in the model are discussed.

H3: The research groups that are provided with more external financial resources from public funds will generate more technological knowledge.

By the obtaining of financial resources of external character, we are referring in our case to the financing provided by the central government (the Ministry of Education and Science), which has traditionally financed basic and applied research in public research institutions. The existence of this financing is also an indication of the quality of the group as researchers.

H4: The groups that are capable of capturing larger amounts of financial resources from companies will generate more technological knowledge.

In our case, the existence of relationships between the research group and relevant companies is an item that will enable us to check if knowledge of the market and of the needs of the relevant productive sector, obtained through contact with such companies, is a determinant in the generation of technological knowledge.

H5: The institutional profile of the research group will influence the generation of patents.

In Spain, and therefore in Andalusia too, there are various different public bodies dedicated to research. The inclusion of this hypothesis is very appropriate now, not only because the way research is organised varies widely between institutions, but also because their policies in respect of the generation of patents are very different.

3. Methodology

In order to establish the factors determining the generation of technological knowledge in the universities and public research institutions of Andalusia, the approach will be to follow an adaptation of the classic empirical formulation of function of production put forward by Griliches (1979) and modified by Jaffe (1989), Feldman (1994) and Audrestch and Feldman (1996), to include the spatial dimension:

$$PAT_i = f\,(S_i, P_i, C_i)$$

where the variable PAT measures the generation of technological knowledge in the universities and OPIs (public research institutions).

The patents will theoretically be determined by a set of variables that can be grouped under three headings: S_i is a set of variables related to the capabilities and scientific qualifications of the researchers; P_i is a set of variables that measures the extent to which the researchers have public or private financing, and C_i is a set of variables related to the characteristics of the researchers.

There are various possible ways of treating this function of production econometrically:

a) If we intend to investigate the existence or absence of patents, it would be more appropriate to utilise binary response models. In this case, we opt for a Logit type model that determines the causes behind a researcher or research group seeking to patent an invention.[1]

b) Secondly, the nature of the data suggests the formulation and estimation of a count model to quantify the intensity in the generation of technological knowledge (Poisson or Negative Binomial). The application of a Poisson model requires the assumption of equality of means and variances, a requirement that cannot always be met in practice. If the data show overdispersion, the standard

[1] A formal presentation of this type of model can be found in Greene (2003).

errors of the Poisson model will be biased towards the low end, thus providing high values for the individual significance statistics (Cameron and Trivedi, 1986). The generally accepted model for avoiding this overdispersion is the Negative Binomial (NB2, in the terminology of Cameron and Trivedi (1986)). In this model, it is assumed that the variance is a quadratic function of the mean.[2]

c) Thirdly, from observation of the data, with a significant number of observations with the value 0 (only a small proportion of all groups seek patents), it can be expected that the process that generates the data is formed by two regimes: one that defines the capacity for the generation of technological knowledge, and another that defines its intensity. A variant for dealing with the excess of zeros was presented by Lambert (1992) and analysed in detail by Greene (1994); it concerns the Poisson and Negative Binomial models with inflated probability of zeros, where the value zero can be originated by a binary process or by a Poisson process (or, where applicable, by a Negative Binomial process).

In our case we opt for a first battery of models of binary type to determine what factors influence whether a research group seeks patents or not, and a second set of models for the count data utilising the models with inflated zeros, of both the Poisson and the Negative Binomial types.

The variables utilised in the empirical models are the following:

Dependent variables:

Pat: this is a dichotomous variable (1 if the group has obtained a patent, 0 if not).
NumPat: this is a count variable (number of patents applied for by each research group).

Independent variables:

[2] The density function, the logarithm of the likelihood function, the first order conditions, and the rest of the statistical formulations and mathematics can be found in Cameron and Trivedi (1998).

H (human resources) has been quantified taking the number of researchers with doctorates, graduates and support personnel in the research group (numinv) and by the number of those with doctorates in the group (numdr).
S (Scientific capabilities) has been quantified by the number of scientific publications of international character by the research group (revinter) and the number of publications in journals of national scope (revnac).
F (financial resources) has been obtained from two quantitative variables: one variable picks up the number of projects for which the group has or has not received external financing of public character (proyfin), and the other is the number of contracts for which the group has received private financing (conlru) (Internal financing -originating from the regional government- has not been incorporated because that is a direct function of the variables H and S)[3].
O (Other characteristics of the research group): a set of binary variables has been included to capture the scientific area covered by the research group (agriculture -agr-, health sciences and technologies -cts-, life sciences -cvi-, physics, chemistry and mathematics -fqm-, production technologies -tep-, natural and marine resources -rnm- and information and communications technologies -tic). In this group of variables, two fictitious ones have been included to pick up the type of institution within which the group functions (university -univ-, higher council for scientific research -csic-, or the Regional Government of Andalusía).

4. Data

The region of Andalusia, from which the population of research groups has been extracted (the sample is of the comprehensive type) organises research utilising a structure of research groups according to the scientific areas in which they work. In the technical and scientific areas, i.e. those where there is the theoretical possibility of protecting an invention with a patent, there are 1155 groups; of this total, there is reliable data for 1146; these account for a total of 6,451 researchers with doctorates. Out of all these groups, a total of 167 have obtained one or more patents, producing a total number of 297 records of patents.

[3] Information on the financial amounts of the Projects and Contracts with companies is not available.

The groups belong to various different institutions; the majority are university research groups, although there are also groups belonging to the Junta de Andalucía (basically formed by researchers in public hospitals and regional research institutes) and to the Higher Council for Scientific Research (public research institutes for which the Spanish central government is responsible).

Table 1 presents the variables considered for testing the hypotheses formulated in the preceding part.

TABLE 1

DESCRIPTIVE STATISTICS

	Mean	Std.Dev.	Maximum	Minimum
PAT	0.145	0.352	1	0
NUMPAT	0.257	0.915	15	0
REVINT	16.503	16.758	117	0
CONGINT	13.806	15.093	118	0
UNIV	0.809	0.394	1	0
CSIC	0.094	0.292	1	0
PROYFIN	7.647	9.793	170	0
CONTLRU	2.104	5.850	86	0
NUMDR	5.629	3.424	31	1
NUMINV	10.028	6.026	66	2
AGR	0.096	0.296	1	0
CTS	0.281	0.449	1	0
CVI	0.134	0.341	1	0
FQM	0.181	0.385	1	0
TEP	0.087	0.281	1	0
RNM	0.157	0.364	1	0

Source: Spanish Patent Office and Plan Andaluz de Investigación.

5. Results:

To test the initial working hypotheses, it was decided to propose different types of econometric model; this would also contribute to making the final conclusions more robust.

Given the nature of the data, the following models have been calculated:

- A first type, in which the dependent variable is a binary variable (PAT), in which the reasons why a research group has or has not obtained a patent are analysed. The model chosen is of the logit type. To test the influence of the size of the group on the dependent variable, we have calculated two models, with identical characteristics, in which the only change is that the variable NUMDR is replaced by NUMINV[4].

- A second type of model, in which the dependent variable is a count variable (NUMPAT), in which the reasons why a research group presents either no patents or else a certain number of patents are analysed. The model chosen is of the negative binomial type, which is preferred to that of the Poisson type and to that of the Zero Inflated Poisson and Negative Binomial one, in all the cases[5]. Also in this case, the importance of the size of the group has been tested with two variables.

To make the results more robust, three combinations of variables have been calculated: one with original data, another with logarithms in the quantitative variables, with the object of avoiding the dispersion derived from the size of the group, and the third with the explanatory quantitative variables relativized by the number with doctorates in the research group (NUMDR), in order to minimise the influence of the group size on the result, although in this case the interpretation will be related with the researchers productivity.

The models are shown in tables 2, 3 and 4:

[4] We have estimated both models with identical results. We offer only NUMDR models.
[5] The models has been chosen using the common statistics (overdispersion, Vuong, etc.) and AIC, BIC and CAIC statistics suggested by Cameron and Trivedi (1998).

TABLE 2

MODELS WITH ORIGINAL DATA				
	Results of Logit models (dep var PAT).		Results of Negative Binomial (dep var NUMPAT)	
	Model I		Model III	
	Coeff.	Std.Err.	Coeff.	Std.Err.
ONE	-2.633 *	0.404	-4.142 *	0.925
REVINT	0.023 *	0.006	0.024 *	0.007
REVNAC	-0.027 *	0.012	-0.046 *	0.013
CSIC	0.689 *	0.270	0.565 **	0.299
CONLRU	0.038 *	0.014	0.032 *	0.014
PROYFIN	0.006	0.010	0.027 *	0.013
NUMDR	0.044	0.030	0.076 *	0.033
AGR	0.011 *	0.416	2.072 *	0.682
CTS	-0.398	0.440	1.394 *	0.659
CVI	0.634	0.402	1.799 *	0.660
FQM	-0.179	0.416	1.539 *	0.647
TEP	0.416	0.451	2.621 *	0.726
RNM	-0.652	0.451	0.509	0.659
Alpha			3.504 **	2.025
LR stat		117.878 *		233.107 *
McF Rsq		0.124		
N obs.		1146		1146

* Sign. 5%; ** Sign.10%.

TABLE 3

MODELS WITH LOGARITHMS IN THE VARIABLES				
	Results of Logit models (dep var PAT).		Results of Negative Binomial (dep var NUMPAT)	
	Model I		Model III	
	Coeff.	Std.Err.	Coeff.	Std.Err.
ONE	-2.633 *	0.404	4.228 *	0.916
LREVINT	0.023 *	0.006	0.025 *	0.007
LREVNAC	-0.027 *	0.012	-0.044 *	0.013
CSIC	0.689 *	0.270	0.563 **	0.300
LCONLRU	0.038 *	0.014	0.034 *	0.014
LPROYFIN	0.006	0.010	0.025 *	0.013
LNUMDR	0.044	0.030	0.398 *	0.192
AGR	0.011 *	0.416	1.922 *	0.655
CTS	-0.398	0.440	1.228**	0.637
CVI	0.634	0.402	1.652 *	0.635
FQM	-0.179	0.416	1.410 *	0.625
TEP	0.416	0.451	2.509 *	0.700
RNM	-0.652	0.451	0.347	0.641
Alpha			3.549 **	1.951
LR stat		117.878*		232.849*
McF Rsq		0.124		
N obs.		1146		1146

* Sign. 5%; ** Sign.10%.

TABLE 3

MODELS WITH VARIABLES RELATIVIZED				
	Results of Logit models (dep var PAT).		Results of Negative Binomial (dep var NUMPAT)	
	Model I		Model III	
	Coeff.	Std.Err.	Coeff.	Std.Err.
ONE	1.905 *	0.378	-2.418 *	0.516
REVINTW	0.145 *	0.034	0.170 *	0.039
REVNACW	-0.075	0.057	-0.291 *	0.077
CSIC	0.603 *	0.268	0.383	0.304
CONLRUW	0.136 **	0.070	0.124	0.102
PROYFINW	-0.036	0.044	0.008	0.050
NUMINW	-0.028	0.076	-0.042	0.082
AGR	0.674 **	0.388	1.249 *	0.527
CTS	-0.873 *	0.406	0.397	0.507
CVI	0.189	0.378	0.809	0.509
FQM	-0.524	0.396	0.576	0.501
TEP	-0.031	0.428	1.664 *	0.531
RNM	-0.996 *	0.428	-0.379	0.555
Alpha			4.456 *	1.081
LR stat		94.249 *		282.081 *
McF Rsq		0.099		
N obs.		1146		1146
* Sign. 5%; ** Sign.10%.				

6. Conclusions:

With the object of researching the causes that influence the production of patents in public research institutions, and of answering the questions initially proposed, diverse empirical models have been formulated and estimated, leading to the following conclusions:

1. The human resources that are deployed in the group is a determining element for the generation of patents. We only obtain an irrelevant variable when the number with doctorates, as a proportion of the total number of researchers of the group, is included[6]. Therefore, any system of financing or stimulus to innovation linked to the dimension of the group will have the effect of increasing the technological results susceptible to patent protection. On this point, part of the regional policy for the financing of research groups, in which the dimension of the group constitutes a variable of distribution, goes in this direction. Even so, suspicions derived from a certain bias of dimension may

[6] This case is not so important because we can not consider the rate of doctors a quality indicator; there are a lot of differences among scientific areas (laboratory personnel, etc).

affect this variable, and although this bias may be minimised with the logarithm of the variable, it is always there.

2. The greater the scientific capabilities of a group, measured by the number of publications of quality in international journals, the greater will be its capacity for the generation of patents. Opposed to this, the publications of national character, understanding these to reflect the work of research groups of less scientific quality, provide significant parameters but with negative sign. These results lead to the view that scientific excellence has a positive effect on the generation of scientific knowledge, while research that is more "local" in scope does not stimulate applications for patents.
Therefore, the indicators of scientific quality linked to the award of projects or financial assistance constitute a valid system bearing in mind their incidence in the generation of patents.

3. External financing linked to public research projects (measured by the number of projects awarded) has an effect on the propensity of a group to seek patents, and on its number of patents, although always in the negative binomial models. External financing linked to private research contracts with companies (measured by the number of contracts) also has a positive effect on the generation of patents, although, in this case, in both, logit and count models.
Although the stimulus of research projects, traditionally those with a greater scientific than technological weight, is a useful incentive for generating patents, it appears evident that a more effective measure could be linked to stimulating contacts between companies and public institutions, since it is found that more research of the applied type arises from such contact, and it gives researchers more knowledge of the demands of companies.

4. Differences between the types of institution are appreciated when it come to seeking patents. The differences in favour of the CSIC (Research institutes without teaching obligations) appears in all the models, therefore we could speak of differences imputable to the institution, for reasons of organisation, policy on patents, etc. The CSIC has personnel working only in research, contrary to universities and Junta, and has a marked policy patent. This is not the case of universities and Junta.

5. The scientific areas better placed to generate patents are the fields related to agriculture (AGR) and production technologies (TEP); therefore a policy that aims to increase the number of protected inventions should preferably deploy more resources in these areas.

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