University patents: output and input indicators... of what?

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The increasing public and institutional support for university patents has opened two major sources of debate: First, does this emphasis affect the quality of research? Second, are university patents an effective mechanism for university-industry interaction? Our aim is to address both questions by clarifying the nature of university patents as outputs of different types of research and inputs of diverse instruments of interaction. We focus on the case of the Polytechnic University of Valencia at departmental level. We first construct a patent production function to discriminate what kind of research gives rise to patents and, second, several funding functions to find for which instruments patents are a better input. University patents appear to be an output of costly and long-term oriented research, either publicly or privately financed –in this latter case, through an indirect effect, the provision of industrial knowledge–, and also the input of a certain type of interaction –not through licensing but through signalling competencies. The fear that university patents affect negatively the quality of research is not justified, as they are the outcome of research at the frontiers of science. However, it is true that university patents only stimulate interaction with those firms that have enough absorptive capacity. If interaction with less capable firms is intended, other instruments are required.

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1. Introduction

Many authors have seen increasing university-industry interaction as a natural consequence of changes in societies' needs from universities (Gibbons et al., 1994) and even as positive for the way in which science is organized (Etzkowitz and Leydesdorff, 2001). However, the economics of science approach (Dasgupta and

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David, 1994) defends internal reward mechanisms as being enough for the efficient production of science. In fact, over-emphasis on interaction with industry may hide a narrow conception of the benefits from academic research, as interaction promotes only its direct contribution, which is less important than the indirect one (Salter and Martin, 2001).

Some empirical evidence supports this assertion and focuses on university-industry interaction with two main concerns: first, is university-industry interaction affecting the quality of research? Among others, Lee (1996) finds that it may threaten fundamental research and Geuna (1999) that it has lead to a polarization of universities. Second, do university-industry interaction efforts foster effective interaction? For instance, although Meyer-Krahmer and Schmoch (1998) consider interaction as a two-way bridge, they see the risk of lock-in effects. Beise and Stahl (1999) distinguish between the applied orientation of universities and successful technology transfer.

Patenting and licensing activities of universities are among the main instruments promoted and used to interact with industry, and they have therefore mirrored the above debates. This phenomenon is the motivation for this paper and determines the rest of its structure. Section 2 explains how treating patents as output or input indicators is a useful approach to each of the above concerns. Section 3 presents an econometric model that considers university patents as an output indicator, the sample we will use to test it, and the results of the estimation. Section 4 includes a second model and estimation, taking university patents as an input indicator. Section 5 concludes and gives guidelines for future research.

2. The university patent debates

2.1. University patents as output indicators

University patents are a measure of research production, and have therefore been the subject of studies in the tradition of those that used scientific papers as an output of academic research. However, while the latter placed the emphasis on individual scientists, the former focuses on universities, partly because of the databases available. Thus, following the attempt of Adams and Griliches (1996) to find an econometric relation between number of papers or citations and expenditure on R&D at university level, other authors have tried to find a similar link between university patents and R&D expenditures.¹ Payne and Siow (1999), Foltz et al. (2000 and

¹ This may, in turn, be seen as an application of the knowledge production function of Pakes and Griliches (1984) to the context of industrial firms.

2001), Coupé (2001) and Carlsson and Fridh (2002) have shown that R&D expenditures (with a control for size) and the strength of industrial liaison offices (ILOs) have a positive, significant influence on patenting.² Size, on the other hand, measured through the number of faculty, is not generally significant, nor is the legal change of the Bayh-Dole Act³. They also prove that other internal forces may affect patenting, e.g. patenting experience, as well as other external forces, e.g. R&D spillovers. There are some mentions to the fact that past licensing income may stimulate future patent application, but the lack of data impedes them to test it.

This set of studies is focused on evidence from the US case. There are no econometric studies of university patents in Europe, although the phenomenon is as important as in the US, and it is necessary to apply a rigorous method of quantifying their relationship to some input variables⁴. This may show some idiosyncrasies of Europe in contrast with the US, of relevance for policy making.

A caveat with regard to this set of studies is that they use evidence at the macro-level, although we may wonder whether universities are the best units of observation. Universities are composed of heterogeneous research units which vary in their types of scientific production, funding structure, homogeneity of research themes, modes of co-ordination, role of trust, etc. (Joly and Mangematin, 1996.) More basically, they vary in scientific field and institutional recognition, and macroeconometric models do not consider these differences when estimating the impact of R&D on patenting. Neither do they consider the possibility that patent applications is concentrated in single star inventors (Wallmark, 1998).

In any case, treating university patents as an output of academic R&D has raised a first normative debate: Are patents the result of less useful academic research, that is to say, research aiming at a small, direct contribution to practical application? Etzkowitz (1998) denies this, affirming that university patents are a natural result of “entrepreneurial scientists” as their research “is typically at the frontiers of science and leads to theoretical and

² Thursby and Kemp (2001) enter the debate with another econometric approach, efficiency analysis, although their conception of inputs and outputs is very similar to these studies.

³ The Bayh-Dole Act was enacted by the U.S. Congress in 1980 and became effective on July 1, 1981. The Act transferred the rights to intellectual property generated under federal grants to the universities. It is customary to discuss whether it caused the bulk of the rise of university patents thereafter or it simply ratified an existing trend.

⁴ Our bibliographical review found statistical studies about the Swedish case (Wallmark, 1998), the Italian case (Piccaluga, 2001; Balconi et al., 2002), and a comparison between France, Italy and Spain (Cesaroni and Piccaluga, 2002). None of them apply econometric methods.

methodological advance as well as invention of devices”. On the other hand, Pavitt (1998) does not consider university patents a relevant contribution to innovation, and fears that efforts to conduct research leading to patents may distort or diminish the resources devoted to other more useful research. Regarding patents themselves, Henderson et al. (1998) showed that in the US, the promotion of university patents has diminished the quality of these patents. Mowery and Ziedonis (2002) attribute this to incumbent universities that started patenting after the legal stimulus of the Bayh-Dole Act.

Patent production functions help to clarify this debate, distinguishing among types of R&D that may give rise to patents. Among the studies quoted above, at least Foltz et al. (2000 and 2001) decompose R&D by source of funding and find that government funds for R&D have a greater influence on patenting than those from industry. If we assume that the former tend to finance higher quality research (i.e. more long term oriented and more costly), it would imply that the fear that university patents threaten the quality of research is not justified.

We may wonder, though, whether what matters is not only the sources of funding, but also the instruments of funding. By “instrument”, we mean different kinds of grants and contracts, that can be linked to some precise notion of quality rather than simply assuming a link between source and quality. To that end, we need to use databases that contain information on such instruments, e. g. the internal contract databases of universities. For this reason and the one given above, of studying research units, we advocate the need for case studies such as the one we will present in our estimations.

2.2. University patents as input indicators

There are two dimensions that allow us to consider university patents as the input of concrete results: licenses and funding.

The first dimension, patents as a proxy of licensing activities, has been widely studied. The traditional justification for university patents is that they offer protection to firms and visibility to universities, stimulating technology transfer through the license. That was the rationale behind the Bayh-Dole Act in the US (Mowery et al., 2001), but is also the current political view in Europe. Schmiemann and Durvy (2001), members of the Innovation Policy Unit of the Enterprise Directorate-General, illustrate the position of the European Commission. For them, the efforts of US universities towards commercialisation, with patents at the forefront, have stimulated technology transfer and economic growth, so this is a model to be followed in order to narrow the productivity gap with the US. The mission of the European Commission should therefore be to give

incentives to universities to take into account patent rights and other mechanisms of intellectual property protection.

In addition, for Meyer-Krahmer and Schmoch (1998), “a patent only makes sense for a scientific institution if it is interested in the commercial exploitation of a new finding and a collaboration with an industrial partner is aimed at or already exists. Therefore, 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”. Finally, Wallmark (1998) considers patents valuable as their licensing helps to create employment, especially among graduates if spin-off firms exploit the patents.

The second dimension, patents as a means of attracting funding, has received less attention, but it is undeniable. They are a signal for obtaining public funding, since they may appear as “a merit in the CV of researchers” (Wallmark, 1998.) Besides, they are a signal for obtaining private funding, in two ways. First, firms that perform technology watch interpret patents as a signal of the competencies of the inventors, e.g. the academic research group, with which firms may contract to perform R&D in their field of excellence, rather than to obtain a license for their patent. Second, patent license agreements are usually accompanied by additional contracts to transmit expertise and know-how.

The treatment of university patents as an input indicator brings to mind a second normative debate: Does university patenting really foster university-industry interaction? Rappert et al. (1999) show that, in the UK case, industrialists do not appreciate formalization through patents, given that interaction relies on informal trust-based relationships. Therefore, patents may even cause tensions, alleviated only if spin-off companies, which tend to keep closer links with universities, exploit them. Mowery et al. (2001) argue that patents in the US replace what were formerly just public results, now subject to administrative procedures that may raise the cost of use. Nelson (2001) adds that the visibility provided by patenting is not enough to attract companies without additional efforts by the technology transfer offices. Mowery and Sampat (2001) find in the historical case of the Research Corporation, which was in charge of licensing university patents in the US until it was finally dismantled, a good example of failure of this activity.

One way to analyse this aspect would be through econometric testing of the impact of patents on different kinds of funding. Again, only the internal databases of universities allow us to do this, reinforcing the need for case studies. We will perform this kind of analysis in section 4.

3. An econometric model of a case study (I): University patents as output indicators

3.1. The econometric model

Section 2.1 reported some previous econometric works that consider university patents a function of R&D expenditures, number of faculty, licensing income and exogenous time shocks (number of staff at the ILO, R&D spillovers, legal changes). We argued that, additionally, we should consider among the independent variables microeconomic forces like scientific field, institutional recognition and the presence of star inventors. Our database allows us to include all these variables. Therefore, we plan to estimate the following production function:

$$pat_{it} = f(rd_{i,t-1}, pers_{i,t-1}, sci_i, rest_i, joi_i, star_i, lic_{i,t-1}, time_t); i = 1, \dots, N; t = 1, \dots, T \quad (1)$$

The dependent variable *pat* represents patents. We express it as a function of the following independent variables: *rd* is expenditure on research and development, *sci* and *rest* are groups of scientific fields: *sci*, are fields active in science-based technologies; *rest* are fields with restrictions on patenting, *joi* represents institutional recognition –in our case, the status of joint institute funded by both the university and another research organization; *star* indicates the presence of star inventors, respectively. *Sci*, *rest*, *joi* and *star* are time invariant characteristics of research units. *Lic* is the amount of money obtained by university through patent licenses. *Time* is a trend, representing external forces that affect all research units at the same time. The subscript *i* corresponds to the observed individual or research unit and the subscript *t* to the year.

Our intention is to apply the model to data from the Polytechnic University of Valencia (UPV). We believe that the UPV is significant to study the patenting activities of Spanish universities, as it is the third national university in terms of Spanish Patent Office (SPO) issued patents and the second in the European Patent Office (EPO) ranking (Cesaroni and Piccaluga, 2002). It is also representative of young European universities (it is thirty years old), characterized by their small size, technological research and less consolidated public funding, which made them prone to heavy dependence on industry (Geuna, 1999). The UPV has engaged in increasing interaction activities through a relatively well-endowed industrial liaison office and a pioneering program to support the creation of spin-off companies. However, public funding has grown at a faster rate than private funding, as an internal policy response to keep up a certain standard of quality in research. Fernández de Lucio and Nieto (1998) give it as an example of an “entrepreneurial university” according to the features identified by Clark (1998).

We collected data for the ten-year periods running from 1991 to 2000 in the case of patents and 1990 to 1999 in the case of the substantive explanatory variables. We considered 43 different departments or institutes as representative individuals or research units.⁵ The resulting database is therefore a 430-observation panel.

The information on patents and R&D comes from two databases of the Center for Support of Innovation, Research and Technology Transfer (CTT), the industrial liaison office of the UPV. One is a patent database and the other is a database of R&D grants and contracts. We assigned patents to departments through the name of the inventors, having a nominative list of the members of the various departments. For each R&D grant or contract, there was a responsible person and the database specified her department. Therefore, it was possible to link patents and amount of R&D by department.

This is the list of variables as we measured them:

- *Pat*: number of patent applications by department and year.⁶ Although it is more common to use issued patents in this type of econometric studies in order to analyze worthier inventions, applications and issues coincide in the UPV's case in the medium term.⁷ This means that studying one or another makes no

⁵ We made some adjustments in view of the evolving nature of the UPV (typical of any academic institution). Two departments or institutes were created during the period, but we did not include them in the panel. Two others split, but we considered the new units as a single one. We did the same in the case of one institute that integrated into a department. On the other hand, interdepartmental mobility of personnel is extremely unusual. The accounting system occasionally attributed R&D to units such as governing bodies (e.g. vice-rectorates) or schools, which we did not include, since they do not produce the same kind of research output as departments or institutes.

⁶ There are three ways to patent: through the national, European or international patent offices. When an inventor chooses one of them, the corresponding patent office gives one year of protection whether or not the patent is finally issued, in exchange for the publication of the application. This gives an incentive to choose one office and then wait for a year before applying through another, so that the period of protection extends from office to office. UPV follows this strategy, so that for every European or international application there is a parallel national application. We opted to count every application in these cases only once.

⁷ The SPO issues patents that meet the requirements of just a formal analysis, not an analysis of contents. The rate of issuing is therefore high in general. In the case of the UPV, with specialised personnel in the technology transfer office to fill in the patent application forms, the rate is 100%.

difference and it allows us to analyze a longer period, as we need not take into account any delay in issuing a patent.⁸

- *Rd*: cost of the research and development activities financed through grants and contracts, in 1986 pesetas (using the GDP deflator) and in logarithms.⁹ It includes heterogeneous funding from different sources and instruments which we will explain in detail. We assumed at least a one-year lag in order to prevent endogeneity as much as possible.
- *Pers*: logarithm of the number of teaching staff and researchers employed by the department or institute. The data comes from the central administration of the UPV.
- *Sci*: dummy variable that takes value one for departments in science-based technological fields (electronics, electrical, chemistry and biotechnology). The list of departments classified as science-based ones appears in the appendix.
- *Rest*: dummy variable equal to one if the department has natural and/or legal restrictions on patenting (e.g. social sciences and humanities in the first case, plant and animal breeding and software in the second case), independent of time. The classification of departments by this category is in the appendix.
- *Joi*: dummy variable equal to one for joint institutes, which are those funded by both the university and another research organization, e.g. the Spanish High Research Council (SHRC). In contrast with departments, they do not have teaching responsibilities, so they can focus on research and this may have an impact on patenting. There is only one such institute in the sample, the Institute of Chemical Technology.
- *Star*: dummy variable equal to one for the departments with star professors, defined as those who persistently patent after a given year. There is only one in the sample, the Department of Food Technology.
- *Lic*: logarithm of the value of contracts for licenses of patents.
- *Time*: year of the patent application, to include the trend effect.

We would like to decompose our measure of R&D expenditures according to the institutions that finance them. To that end, it is convenient to briefly explain the Spanish system of university research, which is based on

⁸ There is another concern that is more relevant. The use of patent counts has the undesirable implication of treating all patents as if they had the same value, which is obviously not true. Many studies use patent citations instead, in order to weight the value of each patent. Unfortunately, there is no computer database for patent citations in the Spanish case.

⁹ Therefore, it does not include other R&D resources such as payrolls, current expenditure or purchase of equipment charged to the university budget. However, a proxy variable of all these is our measure of size.

grants and contracts. On the one hand, grants mainly rely on national, regional and European public sources. There have been four-year long National R&D Plans since 1988 that fund R&D projects, scientific infrastructure and research fellowships. Regional R&D Plans tend to adapt National R&D Plans and they fund the same topics for the region's research groups (in our case, the Valencian R&D Plan). The European Union funds university research through the Framework Programmes and, in the case of regions defined as objective 1 (like the Valencian Community), through the ERDF. On the other hand, from 1983, the University Reform Law allows universities to contract with governments, industry, public research centers and other sources and obtain additional funds, and professors to get part of them. Research base funds of public universities are insignificant because their budgets are based on teaching and not on research (1% of total funds in the case of the UPV).

Our database distinguishes four types of institutions: government, industry, public research centers and others. This allows us to test the next model:

$$\text{pat}_{it} = f(\text{rd}_{i,t-1}^s, \text{pers}_{i,t-1}, \text{sci}_i, \text{rest}_i, \text{joi}_i, \text{star}_i, \text{lic}_{i,t-1}, \text{time}_t);$$

$$i = 1, \dots, N; t = 1, \dots, T; s = \text{gov, ind, prc, os} \quad (2)$$

This is the list of the new variables:

- Rd^{gov} : logarithm of R&D funded by European, central or regional governments, county and city councils.
- Rd^{ind} : logarithm of R&D funded by private and public, national and foreign firms.
- Rd^{prc} : logarithm of R&D funded by public research centers like the SHRC and associated centers, other research institutes, universities, base funds, etc.
- Rd^{os} : logarithm of R&D funded by other sources, such as foundations, associations, etc.

Finally, the proposed measure of R&D includes heterogeneous types of funding instruments, which the CTT classifies as grants or contracts. Table 1 shows this and sums up the following information. Among the grants, the CTT distinguishes between national (including state and regional level) and European ones. Among the contracts, the CTT distinguishes between four conventional categories labeled as follows: high-risk contracts, technological support contracts, consultancy contracts and other contracts.

This division of contracts deserves further explanation. The CTT (1992) defines high-risk contracts as “studies with specific objectives and high uncertainty as to the results”; technological support contracts as “studies with specific objectives and low uncertainty about the results”; consultancy contracts as “studies without specific objectives, to solve occasional questions”; “other contracts” are just “studies which are not included among the above”.

Our experience as managers¹⁰ suggests that grants and high-risk contracts tend to produce new knowledge. Other types of contracts tend to diffuse existing knowledge, more codified in the case of technological support contracts (which tend to result in reports) and more tacit in the case of consultancy contracts (which tend to result in personal face-to-face contact). The category “Other contracts” should include postgraduate training for firms, fellowships for stays in industry, diffusion and network activities, etc. but we found that it also included much genuine R&D that could fit in other categories. Hence, it is noisy, but it accounts only for 7% of total funds.

This characterization may bear some relation to the nature of the R&D performed through each type of instrument. One way to see it is to characterize grants and contracts by their average funding and length. According to Table 1, European research grants are the better funded and longer-term oriented. National and regional research grants and high-risk contracts provide about the same amount of funds, the former with a wider time horizon¹¹. The latter, however, last for a longer period than technological support and consultancy contracts. Therefore, grants and high-risk contracts finance costly and long term oriented R&D whereas the opposite occurs with technological and consultancy contracts. “Other contracts” show similar characteristics to high-risk contracts, probably because they include some research similar to this category, but we have to be cautious due to their heterogeneity.

Another important feature of this typology is that European grants¹², and all contracts, are not only instruments of funding but also instruments of interaction, since they involve some transfer or exchange of knowledge. Hence, when we include them as an input of patents, we are trying to find if the patents are a result of interaction practices.

Every source of funding of model 2 may use each one of the reported instruments of funding. We can therefore cross the sources and the instruments. Omitting public research centers and other sources for the sake of clarity¹³, we created this third model to test:

¹⁰ Two of the authors, Ignacio Fernández de Lucio and Antonio Gutiérrez Gracia, were heads of the CTT in its earlier years.

¹¹ Notice that the average length of national and regional research grants is short (26 months). The reason is that funding is based on projects, with a maximum length of three years. Nevertheless, consolidated groups link research projects, renewing funding consecutively.

¹² These go to joint projects between a university and an industrial partner.

¹³ Besides, the results show that if they are included, no coefficients are significant.

$$\text{pat}_{it} = f(\text{rd}_{i,t-1}^{s,ins}, \text{pers}_{i,t-1}, \text{sci}_i, \text{rest}_i, \text{joi}_i, \text{star}_i, \text{lic}_{i,t-1}, \text{time}_t);$$

$$i = 1, \dots, N; t = 1, \dots, T; s = \text{gov, ind}; \text{ins} = \text{nrrg, erg, hrc, tsc, cc, oc} \quad (3)$$

The new variables are those that come from the decomposition of *rd*:

- *Rd^{gov-nrrg}*: logarithm of R&D funded by governments through national and regional research grants.
- *Rd^{gov-erg}*: logarithm of R&D funded by governments through European research grants.
- *Rd^{gov-hrc}*: logarithm of R&D funded by governments through high-risk contracts.
- *Rd^{gov-tsc}*: logarithm of R&D funded by governments through technological support contracts.
- *Rd^{gov-cc}*: logarithm of R&D funded by governments through consultancy contracts.
- *Rd^{gov-oc}*: logarithm of R&D funded by governments through other contracts.
- *Rd^{ind-nrrg}*: logarithm of R&D funded by industry through national and regional research grants.
- *Rd^{ind-erg}*: logarithm of R&D funded by industry through European research grants.
- *Rd^{ind-hrc}*: logarithm of R&D funded by industry through high-risk contracts.
- *Rd^{ind-tsc}*: logarithm of R&D funded by industry through technological support contracts.
- *Rd^{ind-cc}*: logarithm of R&D funded by industry through consultancy contracts.
- *Rd^{ind-oc}*: logarithm of R&D funded by industry through other contracts.

We report some basic statistics of variables in the models in Table 2. We can see that the average department applied for 0.26 patents per year, out of a total of 110 patents. The main sources of funding are government and industry, while public research centers and other sources play a lesser role, and quite uneven (notice the large standard deviations). Furthermore, these two often act as intermediaries of funds from government, so the nature of the funding might be very similar. We can also notice that, as one might expect, governments fund R&D mainly through national and regional research grants, while firms make use of various types of contracts.¹⁴

¹⁴ The fact that some categories are not null may be surprising. For instance, why does industry have some (small) amount of funding through national and regional research grants? The answer is that for some grants, it is compulsory for public research centres like UPV to apply together with a company that will finance part of the project. If the project gets a grant, the public funding will be accounted as coming from government, the private part as coming from industry. Another interesting question is why industry appears as a source of funding with funds from European research grants. The reason is that a consortium of partners, led by one of them, applies for these grants. When the leader is the UPV, the CTT will report the money as coming from government. When the leader is one of the other institutions, once it receives the EU funds, it will distribute

Two main limitations hinder the validity of the data. First, the small number of patents (110) in absolute terms –not so small, in relative terms, for a European university. Second, certain subjectivity in the classification of R&D by instrument of funding made by the CTT, which becomes obvious in the noise of the variable “other contracts”. The following estimations attempt to find interesting results despite these limitations.

3.2. Estimations

Patents can only take non-negative integer values. When we try to explain them as a function of a variable measured in monetary terms, such as contractual funding, estimation by least squares does not tend to be appropriate. Instead, count data methods, as proposed by Hausman et al. (1984), usually provide a better fit. The most immediate method is the Poisson estimation, which models the patent variable as the outcome of a Poisson process, but imposes on the distribution the restriction that the mean and the variance of the observations are equal. More sophisticatedly, negative binomial estimation adds a parameter to the Poisson specification to control for the possibility that this assumption does not hold. In our estimations, we applied and tested both techniques and the negative binomial model was always preferred to the Poisson model. Hence, we present the results of the negative binomial regression in this section.

Table 3 shows the results for the first three models. Column 1 presents those for the aggregate measure of R&D. We can see that it has a positive sign. As R&D was measured in logarithms, we can interpret the coefficient as an elasticity, so we find decreasing returns to scale, as do most of the studies reported in section 2.1. However, the significance of the coefficient is weak, which means that it is important to control for disciplinary and institutional differences.

Concerning other variables, the coefficient of personnel is positive but not significant, indicating no economies or diseconomies of scale. Being a department in science-based technologies (*sci*), being a department with restrictions to patent (*rest*), being a joint institute (*joi*) and counting with a star inventor (*star*) have the expected significant effects on patenting, all positive except being a department with restrictions to patent, confirming that they condition the estimation of the coefficient of R&D and the importance of internal characteristics of departments in the process of patent generation. Science-based fields have a higher propensity to patent while the opposite occurs in fields with natural or legal restrictions on patenting. Joint institutes tend to

them among the partners, including the UPV. Then the CTT will compute it as European funds coming from institutions other than government. The remaining categories appear to be fairly intuitive.

patent more, probably because they are devoted only to research and not to teaching. The presence of a star inventor is enough for a department to stand out significantly.

Lic or the value of licensing contracts does not have a significant effect. This does not necessarily mean that revenue from past licenses is neutral in motivating further patenting, but that the distribution of this revenue is too skewed for its effect to be significant.

We also find that the trend, *time*, enters the model with a positively significant coefficient, meaning that some exogenous forces may be impelling patenting. Actually, we tested separately –because they were correlated to each other - some external forces that could be behind this trend: number of personnel of the ILO, R&D spillovers from other departments and legal changes in the regulation of the UPV. All of them were positive, although only the first two were significant.

The results from the estimation of the second model, with R&D split by source of funding, appear in column 2 of Table 3. The only significant, positive coefficients are the ones for government and industry. Remarkably, they are very similar. This challenges the view that the industrial type of knowledge is more applied, and leads to more patenting.

Column 3 helps us to understand the full meaning of this assertion. It shows the regression on the two significant sources of funding, decomposed by instrument of funding. National and regional government research grants have a significant and positive impact on the independent variable. So do industrial high-risk contracts. What matters is that the former is greater than the latter. Hence, by differentiating by instruments of funding we see that public funding is more important for patenting than private funding.

Other important results are that the influence of publicly channeled European research grants on the independent variable is negative, maybe because the partners involved in European projects own the results from research. However, this result is not robust, because it is due to the presence of an outlier: without it, the coefficient is still negative, but not significant. Technological support and consultancy contracts have no significant effect on the independent variable. Therefore, instruments that finance larger and longer-term oriented R&D projects foster patenting, except in the case of European research grants. The category of industrial “other contracts” is significantly positive because it shares the above characteristics, although it is difficult to interpret due to its heterogeneity. We could attribute it to the part of the variable that contains high-risk contracts. In a more extensive way, we could consider that training, mobility and diffusion are instruments through which industrial knowledge informally enters into the department.

4. An econometric model of a case study (II): University patents as input indicators

Models 1 to 3 in the previous section played with the same variables that we need to estimate the impact of patents on licenses and funding. It is a matter of inverting the causal relationship among the variables and then present the next two models:

$$lic_{it} = f(pat_{i,t-1}, pers_{i,t-1}, sci_i, rest_i, joi_i, star_i, time_t); i = 1, \dots, N; t = 1, \dots, T \quad (4)$$

$$rd_{it}^{s,ins} = f(pat_{i,t-1}, pers_{i,t-1}, sci_i, rest_i, joi_i, star_i, time_t);$$

$$i = 1, \dots, N; t = 1, \dots, T; s = gov, ind; ins = nrrg, erg, hrc, tsc, cc, oc \quad (5)$$

There are no new variables in addition to previous models, since at this preliminary stage of our research we just assume that the same variables that affect patents may affect licenses and funding (*pers*, *sci*, *rest*, *joi*, *star*, *time*). However, the lags of *lic*, *rd* and *pat* are different from previous models, so there is not simultaneity with them. Notice that model 5 is sub-dividable into as many functions as types of R&D by source and instrument of funding as we have, i.e. 12.

We present the results of the ordinary least squares (OLS) estimation of model 4 in Table 4. Equations in model 5 form a system and the disturbances may include factors that are common to all of the departments, so we need a most sophisticated technique of estimation, e.g. iterated feasible generalised least squares (FGLS). Table 5 reports the results. To simplify the exposition, we also prepared Table 6, which sums up the type of coefficient found for patents (*pat*). Column 1 indicates when *pat* takes a positively significant coefficient: in the cases of other governmental contracts and of industrial high-risk contracts. This picture is symmetrical with the one found in the previous section, except for the case of national and regional governmental grants. It means that patents attract private funds but not public grants for costly, long-term oriented research. In addition, it implicitly means that they promote interaction with firms able to finance such a kind of research.

Column 2 shows when *pat* is not significant for the dependent variable. Remarkably, this is the case of licenses (*lic*). This indicates that patent applications are not leading to more licenses, perhaps again because there are too few of the latter to allow a significant relationship to be found¹⁵. Other variables on which the impact of patents is neutral are (government and industry) grants, technological support contracts, government high-risk

¹⁵ An anonymous reviewer pointed out correctly that “the delay between patent applications and license income is considerable and that the observation period of ten years is too short for any valid conclusion. [...] Relevant patent activities of Spanish universities started but at the beginning of the nineties, so that relevant license incomes cannot be expected”.

contracts, and industry consultancy contracts and other contracts. These categories include small percentages of total R&D funds or they indicate a kind of interaction that is less demanding of new knowledge, so it is hard to believe that patents, carriers of such knowledge, will significantly promote these contracts.

Finally, patents exert a significant negative influence on the variables ticked in column 3. These are (government and industry) European research grants and government consultancy support contracts. The latter should not be surprising. Concerning European grants, what we observe may mean that there might be some substitutability between them and university patents as ways of interaction with industrial partners.

5. Conclusions and comment about future research

University patents are both output and input indicators. They are the result of academic research and, at least a priori, a means of raising funding through licensing, R&D grants and contracts. To shed some light on the normative debates provoked by the rise of university patents, it is important to identify which type of academic research they are the results of, and the type of funding they attract.

We found that when we consider UPV patents as an output indicator, they are an output of costly, long-term oriented research, either publicly or privately funded (through public national and regional research grants and private high-risk contracts). If the generation of patents relies on this type of research, it is difficult to sustain the assertion that they represent a threat to fundamental research.

The link between industrial funds and university-owned patents should not be interpreted as a direct one, since it would imply that firms do not retain the ownership of the results of their projects, and that is rarely the case. Instead, we may interpret it as an indirect link, an outcome of the acquisition of industrial knowledge by university, following the view that interaction is a two-way bridge (Meyer-Krahmer and Schmoch, 1998.)

On the other hand, when we treat UPV patents as input indicators, we find that they are an input of costly, long-term oriented research funded by industry. In the interpretation of our R&D variables as channels of interaction, the fact that UPV patents attract industry high-risk contracts also means that university patents are the motor of only a certain kind of interaction: interaction with firms that are able to perform technology watch and fund long-term, costly R&D, that is, firms with enough absorptive capacity. It may have regional implications: What if such firms do not exist in the region where universities are located? Supporters of the valorisation of academic research are usually the same as supporters of the importance of the university in the local economy. In the case of university patents, the two logics may be at odds. In any case, if policymakers are

aiming at interaction with another kind of firm, university patents may not be an effective means of achieving this aim.

We also saw that the main mechanism through which patents have an effect is not through licensing but through signalling. Although we must be careful because of the delay between applications and licenses, the usual emphasis on patents as a way of obtaining revenue by licensing them may be exaggerated, and misunderstands their function as attractors of funding. But this function should also raise the question, still unanswered: Are university patents more useful than other academic signals, e.g. scientific publications? It should be taken into account that the management of university patents implies a costly infrastructure, such as professionals at ILOs.

The advantage of getting deep insights into the phenomenon of university patenting by analysing a case study is accompanied by the flaw of a possible lack of generality. The fact that the UPV behaves like American universities in a number of dimensions gives certain robustness to the results. We explored some other characteristics that may be idiosyncratic, e.g. the fact that single departments or institutes, because of their institutional status or the presence of a star professor, may drastically reduce the estimation of the coefficient of R&D; or the fact that licensing does not have a significant influence. We believe that the UPV is representative of young, patenting, “entrepreneurial” universities in Europe, so this type of universities should be the field of application of the results. Nevertheless, our current research will soon allow us to make a comparison with the case study of an older, more science-oriented European university.

We also believe that our quantitative methods should be confronted and complemented with qualitative information, in order to validate the results, especially given the limitations of the database. To that end, we are engaged in interviews with UPV inventors. Actually, there is a certain feedback between econometrics and interviews, since the latter motivated the consideration of university patents as an input of funding and the estimation of the models in section 4. In fact, another future consideration will be to refine the econometric model contained in that section, to take into account more determining factors of contractual funding.

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Appendix. List of departments and institutes included in the panel

Department/Institute	Corresponding technology is science-based (Sci=1)	Limited patenting by nature and/or law (Rest=1)	Joint institute or presence of star inventors (Joi or Star=1)
Dept. of Agrarian Mechanization and Technology			
Dept. of Animal Science		✓	
Dept. of Applied Mathematics		✓	
Dept. of Applied Physics			
Dept. of Architectonic Composition			
Dept. of Architectonic Constructions			
Dept. of Architectonic Projects			
Dept. of Audio-visual Communication, Documentation and History of Art		✓	
Dept. of Biotechnology	✓		
Dept. of Business Organization, Financial Economics and Accounting		✓	
Dept. of Cartographic Engineering, Geodesy and Photogrammetry			
Dept. of Chemical and Nuclear Engineering	✓		
Dept. of Chemistry	✓		
Dept. of Communications	✓		
Dept. of Computer Engineering ¹⁶	✓	✓	
Dept. of Conservation and Restoration of Cultural Heritage			
Dept. of Construction Engineering and Civil Engineering Projects			
Dept. of Design		✓	
Dept. of Economics and Social Sciences		✓	
Dept. of Electrical Engineering	✓		
Dept. of Electronic Engineering	✓		
Dept. of Food Technology			✓
Dept. of Foreign Languages		✓	
Dept. of Graphic Architectonic Expression			
Dept. of Graphic Expression in Engineering			
Dept. of Hydraulic and Environmental Engineering			
Dept. of Land Engineering			
Dept. of Machines and Thermal Engines			
Dept. of Mechanical and Materials Engineering			
Dept. of Mechanics of Continuous Means and Theory of Structures			
Dept. of Painting		✓	
Dept. of Rural Engineering			
Dept. of Sculpture		✓	
Dept. of Statistics and Operational Research		✓	
Dept. of Systems Engineering and Control	✓	✓	
Dept. of Textile and Paper Engineering			
Dept. of Thermodynamics			
Dept. of Transport Infrastructure and Engineering			
Dept. of Urbanism			
Dept. of Vegetal Biology		✓	
Dept. of Vegetal Production ¹⁷		✓	
Institute of Biomechanics of Valencia			
Institute of Chemical Technology	✓		✓

¹⁶ It has limited patenting because computer programs cannot be patented in Spain.

¹⁷ It has limited patenting because new species of plants cannot be patented in Spain.

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Tables

Table 1 Instruments of funding of the UPV, 1990-1999.

Type of instrument	Instrument of funding	Definition (CTT, 1992)	Description	Instrument of interaction	Average funding (euro)	Average length (months)
Grant	National and regional research grants	R&D projects granted to the UPV through national (state and regional) public tender	Production of new knowledge	No	46,199	26
Grant	European research grants	R&D projects granted to the UPV through European public tender, together with another institution	Production of new knowledge	Yes	95,086	28
Contract	High risk contracts	Studies with specific objectives and high uncertainty as to the results	Production of new knowledge	Yes	49,455	15
Contract	Technological support contracts	Studies with specific objectives and low uncertainty about the results	Diffusion of existing knowledge, mostly codified, through reports	Yes	28,390	10
Contract	Consultancy contracts	Studies without specific objectives, to solve occasional questions	Diffusion of existing knowledge, mostly tacit, through face-to-face contact	Yes	17,955	10
Contract	Other contracts	Categories which are not included among the above	Diffusion of existing knowledge, through postgraduate training for firms, fellowships for stays in industry, diffusion and network activities, etc.	Yes	49,070	13

Table 2 Descriptive statistics of non-dummy variables in the models

Variable	Mean	Std. Dev.	Minimum	Maximum
Pat	0.26	1.12	0.00	13.00
Rd	6.39	2.15	0.00	8.40
Rd^gov	5.13	3.05	0.00	8.24
Rd^gov-nrrg	3.32	3.46	0.00	8.09
Rd^gov-erg	0.77	2.19	0.00	7.75
Rd^gov-hrc	1.02	2.40	0.00	7.65
Rd^gov-tsc	1.99	3.01	0.00	8.12
Rd^gov-cc	0.80	2.10	0.00	7.55
Rd^gov-oc	0.56	1.82	0.00	8.09
Rd^Ind	4.83	3.01	0.00	8.18
Rd^ind-nrrg	0.18	1.07	0.00	7.19
Rd^ind-erg	0.12	0.91	0.00	7.68
Rd^ind-hrc	2.18	3.17	0.00	8.04
Rd^ind-tsc	3.24	3.21	0.00	7.94
Rd^ind-cc	2.01	2.92	0.00	7.48
Rd^ind-oc	0.41	1.51	0.00	7.03
Rd^prc	1.03	2.35	0.00	7.44
Rd^os	1.26	2.53	0.00	8.39
Pers	1.47	0.27	0.94	2.11
Lic	0.04	0.51	0.00	6.30
Time	94.50	2.88	90.00	99.00

Table 3 Negative binomial estimation of the models with patents as an output indicator

Variable	1	2	3
Constant	-25.79 (6.06) ***	-24.38 (5.65) ***	-23.97 (5.75) ***
Rd	0.53 (0.34) *		
Rd ^{gov}		0.14 (0.10) *	
Rd ^{gov} -nrrg			0.13 (0.05) ***
Rd ^{gov} -erg			-0.11 (0.05) ***
Rd ^{gov} -hrc			-0.01 (0.07)
Rd ^{gov} -tsc			-0.04 (0.06)
Rd ^{gov} -cc			0.08 (0.07)
Rd ^{gov} -oc			0.04 (0.07)
Rd ^{ind}		0.14 (0.09) *	
Rd ^{ind} -nrrg			-0.07 (0.09)
Rd ^{ind} -erg			0.03 (0.16)
Rd ^{ind} -hrc			0.07 (0.05) *
Rd ^{ind} -tsc			0.05 (0.04)
Rd ^{ind} -cc			-0.02 (0.06)
Rd ^{ind} -oc			0.27 (0.08) ***
Rd ^{Prc}		-0.03 (0.06)	
Rd ^{Os}		-0.07 (0.06)	
Pers	0.76 (0.63)	0.66 (0.68)	0.86 (0.74)
Sci	0.91 (0.40) ***	0.98 (0.42) ***	1.13 (0.38) ***
Rest	-1.96 (0.65) ***	-2.02 (0.71) ***	-2.2 (0.68) ***
Joi	2.8 (0.55) ***	2.63 (0.55) ***	3 (0.42) ***
Star	2.18 (0.58) ***	1.96 (0.61) ***	2.38 (0.55) ***
Lic	0.04 (0.12)	0.02 (0.12)	0.03 (0.11)
Time	0.19 (0.06) ***	0.21 (0.06) ***	0.22 (0.06) ***
δ	0.45 (0.31) *	0.39 (0.30) *	0.01 (0.13)
<i>Log likelihood</i>	-157.26	-154.84	-144.93

Standard errors in brackets. The number of asterisks (one, two or three) denotes the level of significance of the coefficients (10, 5 or 1 percent, respectively). δ is a technical parameter to control for the presence of overdispersion (negative binomial model.)

Table 4 OLS estimation of model 4, with patents as an input indicator

Variable	Dep. Var. : Lic
Constant	-0.55 (0.78)
Pat	-0.02 (0.03)
Pers	0.00 (0.00)
Sci	0.00 (0.06)
Rest	-0.07 (0.05) *
Joi	0.43 (0.20) ***
Star	-0.08 (0.15)
Lic	0.01 (0.01)
Time	-0.55 (0.78)

Table 5 Iterated FGLS estimation of model 5, with patents as an input indicator

Variable	Dep. Var.: $Rd^{gov-nrrg}$	Dep. Var.: $Rd^{gov-erg}$	Dep. Var.: $Rd^{gov-hrc}$	Dep. Var.: $Rd^{gov-tsc}$	Dep. Var.: Rd^{gov-cc}	Dep. Var.: Rd^{gov-oc}
Constant	-26.98 (18.31) *	-42.91 (12.08) ***	13.07 (7.39) **	23.33 (13.96) **	-18.26 (4.66) ***	43.93 (18.10) ***
Pat	-0.43 (0.72)	-1.06 (0.48) ***	0.31 (0.29)	-0.17 (0.55)	-0.25 (0.18) *	1.50 (0.71) ***
Pers	0.01 (0.03)	-0.01 (0.02)	0.00 (0.01)	0.02 (0.02)	0.00 (0.01)	0.01 (0.03)
Sci	11.51 (1.44) ***	4.27 (0.95) ***	-0.77 (0.58) *	-1.46 (1.1) *	-0.78 (0.37) ***	-1.88 (1.43) *
Rest	-0.30 (1.19)	-0.89 (0.78)	-0.10 (0.48)	-1.37 (0.90) *	-0.50 (0.30) *	-1.74 (1.17) *
Joi	-1.88 (4.78)	5.99 (3.15) **	-1.03 (1.93)	0.82 (3.64)	0.89 (1.22)	-6.72 (4.72) *
Star	9.61 (3.58) ***	1.26 (2.36)	-1.24 (1.44)	-2.40 (2.73)	-0.74 (0.91)	-3.64 (3.54)
Time	0.32 (0.19) *	0.47 (0.13) ***	-0.12 (0.08) *	-0.22 (0.15) *	0.20 (0.05) ***	-0.44 (0.19) ***

(table 5 continued)

Variable	Dep. Var.: $Rd^{ind-nrrg}$	Dep. Var.: $Rd^{ind-erg}$	Dep. Var.: $Rd^{ind-hrc}$	Dep. Var.: $Rd^{ind-tsc}$	Dep. Var.: Rd^{ind-cc}	Dep. Var.: Rd^{ind-oc}
Constant	-4.09 (1.58) ***	3.24 (5.10)	-25.19 (15.55) *	28.92 (10.51) ***	-24.75 (4.94) ***	0.51 (1.28)
Pat	0.04 (0.06)	-0.49 (0.20) ***	1.25 (0.61) ***	0.20 (0.41)	-0.17 (0.19)	0.00 (0.05)
Pers	0.00 (0.00)	0.01 (0.01)	-0.02 (0.02)	0.00 (0.01)	0.02 (0.01) ***	0.00 (0.00) *
Sci	0.28 (0.12) ***	1.01 (0.40) ***	2.24 (1.23) **	0.42 (0.83)	-0.01 (0.39)	0.23 (0.10) ***
Rest	-0.15 (0.10) *	0.56 (0.33) **	-2.62 (1.01) ***	-1.61 (0.68) ***	-1.01 (0.32) ***	0.15 (0.08) **
Joi	-0.58 (0.41) *	3.67 (1.33) ***	4.87 (4.06)	-3.96 (2.74) *	-0.34 (1.29)	-0.23 (0.34)
Star	-0.17 (0.31)	0.59 (1.00)	-3.56 (3.04)	-2.41 (2.05)	0.27 (0.97)	-0.02 (0.25)
Time	0.04 (0.02) ***	-0.04 (0.05)	0.31 (0.16) **	-0.27 (0.11) ***	0.27 (0.05) ***	-0.01 (0.01)

Table 6 Summary of the estimated impact of patents on licenses and different kinds of funding

Dependent variable	Pat + ✓	Pat ✕	Pat - ✓
(4) Lic		✓	
(5)			
$Rd^{gov-nrrg}$		✓	
$Rd^{gov-erg}$			✓
$Rd^{gov-hrc}$		✓	
$Rd^{gov-tsc}$		✓	
Rd^{gov-cc}			✓
Rd^{gov-oc}	✓		
$Rd^{ind-nrrg}$		✓	
$Rd^{ind-erg}$			✓
$Rd^{ind-hrc}$	✓		
$Rd^{ind-tsc}$		✓	
Rd^{ind-cc}		✓	
Rd^{ind-oc}		✓	