Patent Production at a European Research University: Exploratory Evidence at the Laboratory Level

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ABSTRACT. Most studies of academic patenting focus on the university as the unit of analysis. In contrast, we examine this phenomenon at the laboratory level. Based on a sample of 83 research laboratories of Louis Pasteur University (ULP, Strasbourg, France) from 1993 to 2000, we constructed a panel data set that allows us to discriminate between patents that are owned by the university and those that are owned by firms and other organizations but invented by faculty members. We use these data to estimate a patent production function and find that university-owned patents are more responsive to specific public funding, while non-university-owned patents are more responsive to industrial funding. Our results also highlight the importance to control for disciplinary and institutional differences, since they significantly affect the production of the different kinds of ULP patents.

Key Words: university patent, European university, laboratory, contractual funding.

JEL Classification: O31, O32, O34, O38, O39

1. Introduction

In recent decades, we have witnessed several fairly disruptive changes in the regulatory environment for university–industry technology transfer (Bayh-Dole Act and European derivatives), in the definition of academic research goals (increase in publication requirements, rise of the mission to contribute to economic development) and, in the public support to science (shortening of funds, evolving rationales, emergence of the European funding level). These changes consequently made the two spheres of science and market more and more connected. In that respect, the major event in the near past is the dramatic increase in university patenting in the US (Henderson *et al.*, 1998; Nelson 2001; Mowery and Ziedonis, 2002). Some authors emphasized that this causes serious risks of a shift from fundamental research to applied research and of a decrease in the dissemination of findings (for evidence on these issues see Cohen *et al.* 1994, 1998; Blumenthal *et al.* 1996, 1997).

While scholars still argue about the risks and opportunities generated by patenting at universities (Pavitt, 1998; Rappert *et al.*, 1999; Mowery and Sampat, 2001), one may acknowledge that little is known about the mechanisms which favor faculty patenting at the micro level. In this paper, we intend to analyze the determinants of academic patenting. Among the factors considered, we dedicate specific attention to contractual funding[1] which is often acknowledged as being non neutral on the definition of academics' research agendas. Thus, the first question addressed is: to what extent do university patents respond to contractual funding? Moreover we deepen this issue trying to stress how contractual support decomposed according to its sources of funding[2] (local public, national public, European, non-profit or industrial) affects academic patenting.

Furthermore, our approach differs from previous econometric studies (Foltz *et al.*, 2000, 2001; Carlson and Fridh, 2002; Coupé, 2003; Payne and Siow, 2003) with respect to the level of analysis: While such studies focused on the university level of analysis, a unique feature of our study is that we go down to the laboratory. Indeed, the laboratory level has been emphasized as the relevant level of analysis of scientific activity (Stephan, 1996; Arora *et al.*, 1998). That is especially true in the (continental) European context and surely when the aim is to deal with funding issues: The laboratory is the

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locus of collective coordination for buying and sharing research facilities, for sharing revenues from intellectual property[3] and for defining research aims (Crow and Bozeman, 1987). The laboratory level also allows us to control for disciplinary differences and for some institutional features. Finally, another important originality of our study linked to European specificities is that it includes not only patents owned by the university but also all patents invented by at least one permanent researcher of the university. This allows us to specifically study the production of different subsets of academic patents built according to both their ownership and their inventors.

Our data cover the period 1993–2000 and concern the research activity of 83 active academic laboratories on which we have reliable and complete information over the period. The laboratories belong to one single university, namely Louis Pasteur University (ULP) in Strasbourg. This university is quite large, diversified, has an old tradition of fundamental research and a long standing of scientific excellence. The Third European Report on Science and Technology Indicators (2003) ranks it first among French universities in terms of impact and 11th among European universities.

The paper is structured as follows: Section 2 summarizes the determinants of university patenting as analyzed in the existing literature and explains how we shall contribute to it. Section 3 presents the model we want to test and the sample we use. Section 4 includes the estimation results. Section 5 concludes and indicates further research lines.

2. The determinants of university patents

We first present below the results of previous studies on academic patenting. We then briefly highlight the original features of our contribution as compared to that body of literature.

A selective survey of the literature

Scholars initially focused on the observation of the recent sharp increase in university patenting and on the factors that may have caused such phenomena. Henderson *et al.* (1998) indicate three of these factors in the US case. The first one is connected to the legal framework: Major changes of the federal law after the Bayh-Dole Act in the early 80s allowed universities to retain the property rights derived from federally funded research. Meyer-Krahmer and Schmoch (1998) and Pavitt (1998) argue that the legal and financial framework is one justification for national differences in university patenting. Secondly, the growing industrial funding of university research may have stimulated patenting. The last factor resides in the substantial increase of technology transfer facilities at universities: Industrial liaison offices (ILO) encourage faculty patenting in order to facilitate further interactions with industry.[4]

More recently, the literature began to focus on the relationship between R&D expenditure and patents by extending to universities the techniques initiated by Griliches (1990) for companies. In that respect, the seminal work of Adams and Griliches (1998) on academic research output functions has been a starting point for the following studies (even if they are using publications as outputs).

Payne and Siow (2003) concentrate on the effect of federal funding on four research outputs, including granted patents. In the case of patents, they use a panel data set of 53 research universities over the period 1975–1994. They apply OLS and IV regression models (plus a Tobit in the case of patents), controlling for university and time effects. They find a positive significant impact of federal R&D and of faculty salaries on patents. The authors conclude that the returns to patents of universities R&D are similar to the ones of firms R&D.[5]

With a cross-section of 142 US universities, Foltz *et al.* (2000) apply a zero-inflated negative binomial model on patent production. They find the effect of federal (plus state) funding to be positive and significant. They consider other financial sources, such as industrial funding and internal funding (own funding plus institutional one), but they do not find them significant. The number of staff members of the ILO matters positively (although with decreasing returns to scale) as well as the ranking of the university. The authors also focus on agricultural biotechnology patents. In this case, they find that only internal funding matters, while neither federal nor industrial funding do. They also show that the infrastructure of agricultural colleges and the importance of agriculture in the local economy are relevant explanations of the model.

In a later work, Foltz *et al.* (2001) propose a dynamic model on a restricted set of agricultural biotechnology patents. They use data from 127 universities over the period 1991–1998, forming a panel of 561 observations, and run a random effect negative binomial regression. They find that patenting experience produces more patents, so that it slows down the catch-up process of lagging universities. Internal funding still has a positive significant impact on patent production, whereas industry funding is still not significant. They separate federal from state funding and find the latter to be positive and significant, while the former is not. The quality of personnel (measured by the average salary of faculty members) is also significantly positive, whereas the number is not. The quality of the ILO (measured through the ratio of patent applications to invention disclosures) matters positively whereas their size does not.

The main concern of Coupé (2003) is the type of returns to scale of university R&D to patents. He applies Poisson and negative binomial regressions on a cross-section of some 500 US universities in 1994 and on a panel of 212 universities and 23 years (from 1972 to 1994). He uses not only patent counts but also patent citations as an output. His main conclusion is the presence of constant or decreasing returns to scale, as in the case of firms. He infers from his results that universities and firms have similar behaviors. He considers different lags for R&D, and distinguishes between public and private universities, among technology classes, university and time effects. He also finds that size (not measured through enrolment but through the number of professors and average salary), university R&D spillovers and, the establishment of an ILO affect positively and significantly university patenting. On the contrary, the legal change represented by the Bayh-Dole Act appears not to have a significant effect.

Carlsson and Fridh (2002) built a survey of 12 US universities to understand the functioning of ILOs and their roles in patenting and licensing activities, start-ups and industry-sponsored research. It allows them to build a conceptual model of the process of technology transfer, which they split into several models (according to the different steps and outputs). These models are also estimated on the larger sample of the AUTM survey (170 universities over 1991–1996). They find that inventions depend on the year of creation of the ILO, on total research expenditure and on the number of staff of the ILO.

The need for a European viewpoint and for micro-data analyses

Among the studies presented above, one may notice that these econometric studies concentrated on North American universities whereas university patenting in Europe may exhibit some important idiosyncracies that should be taken into consideration in a policy perspective[6]. For instance, the focus on US evidence has left aside the patents invented by faculty members but not owned by the university. Indeed, Meyer (2002) and Saragossi and van Pottelsberghe de la Potterie (2003) point out that, in Europe, the set of patents invented by university researchers is much broader than the set of patents their universities own. The contrast with the US situation comes from the high variety in the regulatory environments that face European Universities. In France for instance, there was no need for a Bayh-Dole Act because institutions always had the right to take intellectual property on publicly funded research. Nevertheless, the public research system had until very recently little institutional concern for retaining intellectual property rights. Independently of the legal framework per se universities usually did to retain these rights which were often considered as "counter-productive" in terms of knowledge diffusion or for attracting industrial funding.

The second dimension in which we intend to contribute to the existing literature has to do with the unit of analysis. As the literature review shows, the university is the most common unit of observation retained for explaining patent production. To the best of our knowledge the only studies concerned with academic patenting that looked inside the university are the ones of Wallmark (1997) and of Agrawal and Henderson (2002). Nevertheless, the former study does not provide an econometric analysis and the latter is exclusively concerned with the relationship between publications and patents (it provides no result on other potential determinants). Universities are certainly composed of heterogeneous research units that vary in several respects (types of scientific production, funding structure, homogeneity of research themes, modes of co-ordination, etc.) that may strongly affect patent production. In this respect, the organization of research at French universities is strongly based on laboratories (Joly and Mangematin, 1996). The prevalent organization of research in US universities which gives Principal Investigators a high level of autonomy is not to be found as such in the French system. This institutional context (far from being a methodological constraint) offers an opportunity to go down to the micro-level of research activities (i.e. the laboratory). Laboratories can be classified by discipline, institutional diversity, and size, which thus makes it possible to test some of the micro-determinants of academic patenting which have only been considered by appreciative studies but not included so far in econometric analyses. Getting laboratory level data offers also a chance to collect micro-data on contractual funding that is in France usually managed at the laboratory level. In a production function approach to academic patenting we shall consider all types of funding. Moreover, since we were able to decompose funding according to its source, we intend to determine the elasticity of each source of funding on patent production at the micro-level.

3. Data and methodology

In this section we present our sample and the definitions of the dependent and the independent variables. Once some descriptive statistics are introduced, we describe the methodology used.

The Louis Pasteur University

We use data on the laboratories of Louis Pasteur University (ULP) in Strasbourg (France) which is a quite large and diversified university. It comprises 17 separate institutional components (i.e. schools, education/training and research units, and various institutes) located in six campuses in the Strasbourg area in which around 18,000 students are enrolled. Research and teaching at the university cover a wide range of disciplines. These disciplines exclude humanities and social sciences (except economics, management and geography). ULP has an old tradition of fundamental research and a long standing of scientific excellence. Its researchers received numerous national and international scientific prizes, including the still active Nobel Prize laureate for Chemistry Jean-Marie Lehn (1987) for his contribution to the field of Supramolecular Chemistry. Altogether, the Louis Pasteur University is one of the largest French universities in terms of research. According to the Third European Report on Science & Technology Indicators (2003, p. 311), it is the best French University in terms of impact and the eleventh European one. Such a research capacity is sustained by its close links with major national research institutions such as the *Centre National de la Recherche Scientifique* (from now CNRS, National Center for Scientific Research) and the *Institut National de la Santé et de la Recherche Médicale* (from now INSERM, National Institute for Health and Medical Research).

The data come from several databases. Data on contractual funding, institutional characteristics and teaching and research staff were built specifically for this project and collected from different internal departments within the university (mainly from the ILO and the administrative departments). An important specificity of the database is that we consider the research units which have undergone (and most of the time successfully pass) an evaluation process, to be recognized by central authorities such as the Ministry of Research and/or the CNRS and/or the INSERM. The list of teaching and research personnel was built from the administrative data collected through this evaluation process.[7] In the case of ULP, the database includes almost all the existing research units at the university and the great majority of available teaching and research staff. The data on patents came originally from the French Institute of Intellectual Property (INPI) which we matched with our list of all the teaching and research staff. French, European and PCT patent applications were collected for which at least one inventor appears on our list of personnel.

The patent applications were allocated to the laboratory to which its inventor(s) belong. Matching the different databases induced the selection of the 8 years running from 1993 to 2000 as a period of observation. Our information covers the 83 laboratories which did exist in 1996. We assume that they have been active during the whole period (the assumption is relatively realistic, the research structure of the university being stable during the period). The final panel has then 664 observations.

The dependent variables

It seemed interesting to distinguish between different samples of patent applications according to whether it is the university or a third party that owns them. The reason is that it may reflect different institutional incentive schemes. A second distinction was introduced between academic inventors. Some faculty appeared as inventors of both university-owned and non-university-owned patents while others never had the university as the owner of the patents they invented. The former faculty were identified as inventors of the first circle and the latter as inventors of the second circle.

Once these distinctions are introduced, we propose to study the following four dependent variables at the laboratory level:

- The first one is all patent applications invented by at least one permanent researcher of the lab in year t (pat_t);
- The second variable is the number of patent applications invented by at least one permanent researcher of the lab for which the university is the owner (at least partially) in year t ($Pat\hat{}own_t$);
- The third variable is the number of patent applications invented by at least one permanent researcher of the lab on which the university has no property rights, but for which at least one of the inventors belongs to the set of inventors of the first circle (i.e. who did invent at least one patent owned by the university) in year t ($Pat\hat{}\text{non\_}own1_t$);
- The fourth variable is the number of patent applications for which both the university is not one of the owners and none of its inventors belongs to the first circle of inventors (at least one of them necessarily belongs to the second circle of inventors) in year t ($Pat\hat{}\text{non\_}own2_t$).

Figure 1 intends to clarify the relation between the four types of university patents.

The independent variables

The list of independent variables and their description are the following:

- $Cont_{t\text{-}1}$: logarithm of the contractual funding received at year t, deflated by the GDP deflator. Contractual funding includes R&D contracts, some service contracts (consultancies are excluded), grants, etc.[8] We also differentiate it according to the source of funding: *Nat*: from National government; *Reg*: from regional or local governments; *Eur*: from European Commission; *Ind*: from industry; *Prc*: from public research institutions; *As*: from associations (both public research institutions and associations are non-profit organizations). All values are taken in logs.
- $Dcont_{t\text{-}1}$: dummy variable equal to 1 if the laboratory is a CNRS or INSERM unit and it reports no contracts that year t, which means that its contracts are managed by those institutions (and not by the university). This variable

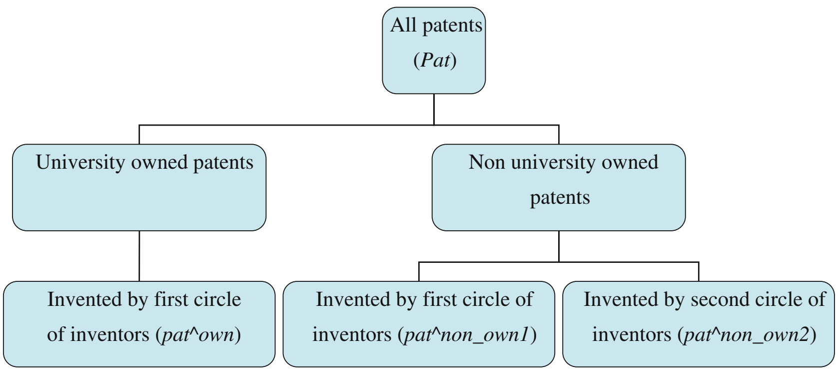

Figure 1. Types of ULP patents.

is a control variable for possible missing contractual funding. It has been built because an important limitation of the data on contracts is that some of the laboratories in the sample are units belonging at least partially to other public research organizations, such as CNRS or INSERM. These laboratories have some degree of freedom to locate the management of their research contracts in one of their parent organizations. As a result of this specific institutional aspect, we had no information about contracts managed outside the university.[9]

- *Size*: size categories, ranging from 0 to 3, according to the number of researchers. While data on contracts are time series, data on laboratories and teaching staff are available only for a single year, 1996. Thus, we could not build a dynamic variable for size but a static variable that we assume to be constant over time. In order to reduce the problem, we did not measure the variable through actual size but through four size categories, delimited by the quartiles of the distribution. We believe that this categorization is eventually more stable.
- *Disc*: a series of dummies for the main disciplines at the university: *bio* (biology), *che* (chemistry), *gen* (genetics), *med* (medicine), *neu* (neurology), *ph* (physics) and *others*—the benchmark, containing other exact sciences and social sciences and humanities. This variable is time-invariant.
- *Inst*: a series of dummies for types of research units at ULP: *uins* (*unité INSERM*, or INSERM unit), *upr* (*unité propre de recherche*, or research unit which are strongly attached to CNRS), *umr* (*unité mixte de recherche*, or joint research unit, i.e. ULP-CNRS or ULP-INSERM), *ea* (*équipe d'accueil* supported by the French Ministry of research), *je* (*jeune équipe* or recognized promising group) and *others* (miscellaneous). The *je* dummy stands for laboratories that are in the process of being supported by the French Government (as *ea* do), while the first three are also recognized by CNRS or INSERM and get extra funding from them. The recognition by a national public research institution such as CNRS or INSERM is the result of a stronger scientific evaluation process of the research outputs, at least every 4 years. Therefore recognition by CNRS and/or INSERM is often a strong signal of scientific (and academic) quality. This variable comes from a peer review process that occurred in 1996 and is thus time-invariant.
- *Time t*: a trend that captures exogenous forces affecting all laboratories (e.g. strength of ILO, contractual funding spillovers and legal changes) and hence laboratory-invariant.[10]

Some descriptive statistics

Table I provides some descriptive statistics of the variables as well as a synthetic description of the variables. The fourth column indicates the distribution of the number of patents according to our categories of laboratories.

The total number of patents is 463, which means that on average every laboratory applied for 0.70 patents per year. The university owns only 62 of those (mean 0.09), firms and other institutions own 153 from the first circle of inventors (mean 0.23) and 248 from the second circle of inventors (mean 0.37).

The total amount of contracts adds up to 67,454,230€ and the average is 101,588€ (values in the table are measured in logs). *Upr* CNRS units which represent 25% of the labs, invented nearly 55% of all patents. The number of teaching and research staff in 1996 was 1400 which means that the average laboratory had 17 researchers, a value between our size categories 1 and 2.

The predominant discipline at ULP is medicine (27% of the laboratories), followed by biology and genetics (14% and 11% of the laboratories, respectively), i.e. 52% are related to Life Sciences in a broad sense. We can see in column 4 that the distribution of patents is somewhat different and much more concentrated. Medicine generated less than 8% of all applications, whereas faculty members in laboratories in the field of genetics invented nearly 37% of all patents with only 11% of all laboratories.

The methodology

Patents can only take non-negative integer values and in the panel context exhibit many zero observations. Therefore a standard linear ass-

Table I
Descriptive statistics of variables in the model

Variable	Description	Mean	Std. Error	Share of patents
Pat_t	# of ULP patents	0.70	1.65	
$Pat\hat{}own_t$	# of ULP owned patents	0.09	0.44	
$Pat\hat{}non\_own1_t$	# of ULP non-owned patents invented by at least one inventor of the first circle	0.23	0.86	
$Patnon\_own2_t$	# of ULP non-owned patents invented by inventors of the second circle	0.37	1.15	
$Cont_t$	Real value of total contractual funding (in log)	3.05	2.90	
Nat_t	Real value of contractual funding from national government (in log)	0.41	1.43	
Reg_t	Real value of contractual funding from local authorities (in log)	0.60	1.70	
Eur_t	Real value of contractual funding from European Commission (in log)	0.86	2.04	
Ind_t	Real value of contractual funding from industry (in log)	1.84	2.62	
Prc_t	Real value of contractual funding from public research institutions (in log)	1.34	2.36	
As_t	Real value of contractual funding from associations (in log)	0.50	1.56	
$Dcont_t$	CNRS or INSERM unit that reports no contracts in the given year	0.24	0.43	
Size	Size categories of number of faculty (four categories from 0 to 3)	1.41	1.13	
Disc	*Discipline*			
Bio	Biology	0.14	0.35	0.227
Che	Chemistry	0.10	0.30	0.082
Gen	Genetics	0.11	0.31	0.367
Med	Medicine	0.27	0.44	0.076
Neu	Neurology	0.08	0.28	0.008
Ph	Physics	0.06	0.24	0.110
Others	Other disciplines	0.24	0.43	0.130
Inst	*Institutions*			
Uins	INSERM unit	0.11	0.31	0.065
Upr	CNRS unit	0.25	0.44	0.546
Umr	Joint unit (ULP-CNRS or ULP-INSERM)	0.23	0.42	0.246
ea	Equipe d'accueil (Ministery of research)	0.23	0.42	0.095
Je	Jeune équipe (Ministery of research)	0.23	0.42	0.095
Others	Other units	0.13	0.34	0.048
Time	Trend	96.50	2.29	

umption is not appropriate. Instead, count data methods as initiated by Hausman *et al.* (1984) are more relevant. The better known method is the Poisson estimation, which models the patent variable as the outcome of a standard Poisson process. Nevertheless this model imposes a restriction on the distribution of the dependent variable namely the mean and the variance are assumed to be equal. In order to account for overdispersion, one can use the negative binomial estimation which adds a parameter to the Poisson specification accounting for individual unobserved heterogeneity. Finally, zero inflated models (both Poisson and negative binomial) estimations introduce a specific regime for zero inflation.[11]

4. The results

We propose to estimate two different models on our four dependent variables. In the first model (Model 1), we include all independent variables without disaggregating contractual funding (*Cont*). In the second model we estimate the full model that is disaggregating the contractual support by source of funding (*Nat*, *Reg*, *Eur*, *Ind*, *Prc*, *As*). This model is referred to as Model 2. In both models, the funding variables (as well as *Dcont*) are lagged 1 year to prevent endogeneity as much as possible.

For each model and for each dependent variable, we started by applying Poisson and negative binomial estimations. Cameron–Trivedi tests indicated overdispersion.[12] Then we applied zero-inflated Poisson and zero-inflated negative binomial models. Several Vuong statistics indicated that the zero-inflated negative binomial were preferred in every case with the exception of the regression on patents owned by the university (*pat^owned*) for which a negative binomial specification is appropriate both for Model 1 and Model 2.

We present successively Model 1 and Model 2 estimates.

Estimations with aggregated funding

Table II presents the estimates obtained for Model 1 specification on our different dependent variables. In the first column, aggregate patenting is the dependent variable. We find that contractual funding has a positive and significant impact as well as the control variable for possible missing contractual funding. The coefficient of *size* is positive and significant as well. Several scientific disciplines dummies (biology, genetics and physics) are also positive and significant, indicating that the probability to patent in these fields is significantly higher than in *others* which is taken as a reference: *others* encompasses disciplines with technical (economics, management, geography) or legal (mathematics, software) restrictions to patent.

As regard to institutional differences, we find that all categories but *je (i.e. Jeune équipe)* patent significantly more than the reference group *others*, and that more prestigious research units (*uins,*

Table II
Estimation of Model 1. All are zero inflated negative binomial estimations but the second one which is a negative binomial estimation

Indep. Var./ Dep. Var.	Pat	Pat^own	Pat^not_own1	Pat^not_own2
Constant	−4.45 (2.5)*	−16.63 (10.65)	−18.43 (6.62)***	−3.52 (2.98)
Cont	0.07 (0.03)**	0.2 (0.16)	0.07 (0.07)	0.03 (0.04)
Dcont	0.51 (0.25)**	1.79 (0.99)*	0.80 (1.23)	0.23 (0.28)
Size	0.27 (0.07)***	0.66 (0.47)	2.06 (0.38)***	0.24 (0.08)***
Disc				
Bio	1.12 (0.22)***	4.23 (1.49)***	5.61 (0.91)***	0.25 (0.27)
Che	0.31 (0.22)	1.2 (2.05)	2.44 (0.89)***	0.19 (0.22)
Gen	1.04 (0.23)***	3.86 (1.32)***	3.02 (1.14)***	0.53 (0.27)**
Med	0.11 (0.22)	2.87 (1.07)***	1.24 (1.09)	−0.32 (0.33)
Neu	−0.62 (0.43)	1.89 (2.15)	0.79 (1.39)	−0.89 (0.62)
Inst				
Ph	0.78 (0.29)***	1.76 (1.88)	8.25 (1.6)***	0.56 (0.31)*
Ea	0.48 (0.25)*	1.34 (1.17)	2.68 (0.64)***	0.84 (0.74)
Je	−0.02 (0.49)		4.10 (1.44)***	
Uins	0.62 (0.31)**	−0.52 (1.7)	−0.98 (1.44)	1.71 (0.99)*
Umr	0.58 (0.25)**	1.73 (1.65)	−1.45 (0.57) **	1.11 (0.93)
Upr	0.67 (0.29)**	0.01 (1.16)	−0.78 (0.81)	1.56 (0.99)
Time	0.03 (0.03)	0.09 (0.12)	0.11 (0.07)*	0.01 (0.03)
Δ	0.67 (0.24)***	2.74 (1.57)*	0.36 (0.32)	0.78 (0.33)**
þ	−1.4 (0.53)***		0.94 (0.30)***	−1.85 (1.12)*
Log likelihood	−601.27	−157.12	−275.84	−386.79
Chi-squared		20.50***		
Vuong statistic	3.08		5.12	2.49

Standard errors are in brackets. The number of asterisks (one, two or three) denotes the level of significance of the coefficients (10, 5 or 1%, respectively). δ and þ are technical parameters to control for the presence of overdispersion (negative binomial model) and the excess of zeros (zero inflated model.)

umr, upr) have the largest coefficients. If we interpret the recognition as a sign of scientific quality, it means that quality is positively correlated to patents. The trend is not significant: Unobserved external forces such as ILO policies, legal changes or funding spillovers that may have occurred during the period covered (1993–2000) did not influence the intensity of the patenting activity.

In columns 2–4 of Table II are exposed the estimated coefficients for the different subsets of patents. We find that contractual funding does not exert a significant impact on any of them. This may mean that the amount of funds explains the generation of patentable results but not whether they will be owned by the university. Only a few variables are significant to explain ULP-owned patents (column 2), so we do not believe that our model is adequate to represent their production process. There are certainly some historical and institutional reasons for the development of a university-specific patenting behavior, and the sample is not yet significant to test any assumptions. The first two disciplines in terms of propensity to patent (biology and genetics) produce patents that will be owned by university or by industry, while the two following ones (physics and chemistry) will focus on industry. On the contrary, medicine, although without significantly more general patents than the average discipline, is more specialized in ULP-owned patents. These results indicate at least that further research will have to be carried on to explain the process underway.

There is some evidence that inventors in the most prestigious laboratories (*uins, umr, upr*) tend to belong to the second circle: They do not patent through the university, but they do patent through industry or other institutions (*pat^not_own2*). The effect is significant for *uins*. Although not significant in the case of *umr* and *upr*, in the case of *umr*, we find a negative, significant effect in the case of firm patents of inventors of the first circle (*pat^not_own1*) which is consistent with the former assertion.[13] On the contrary, inventors in research units evaluated only by the Ministry of research such as *ea* and *je*[14]) tend to belong to the first circle, as shown by the positive, significant coefficients of the second column (*pat^not_own1*). These results are induced by institutional aspects: First the research units linked to CNRS or INSERM had (and have) a propensity to patent under the ownership of these public research institutions, i.e. in these cases the university does not always appear as co-owner of the patent. Only *upr*, *umr* and *unis* are in this institutional configuration. It is partially due to the fact that ULP did use to have its own independent IPR policy. Moreover, CNRS and INSERM being national public research institutions and having active IPR policies, they were able to fund the patent deposit more often than the university (focusing more on *je* and *ea* research units).

The trend becomes significant for *pat^non_own1*. It may mean that external forces such as the ILO or legal changes during the period influenced more the inventors belonging to the first circle in increasing their patenting behavior even if the owner is not the university. However, it is only weakly significant.

Decomposition of contractual funding by sources

The estimates of Model 2 (which includes the funding decomposed by source) are presented in Table III. We find that industrial funding is the only one which influences significantly the propensity to patent, independently of the ownership solution (first column). When distinguishing the ownership and invention regimes, these results hold only for the patents not owned by ULP with an inventor of the first circle. This is due to the fact that, for research funded by industry, the rights on the results are often *ex ante* (contractually) assigned to the company.

The funding by local authorities is the only one that has a significant impact on the number of patents owned directly by the university. Even if further investigations are needed to understand that particular result, it might be due to the "applied" nature of the projects that are likely to be supported by the local/regional authorities which aim to sustain local development. Concerning the patent not owned by the university and with inventor of the 2nd circle, we found no specific effect of the type of funding.

The results obtained so far, and the results obtained in the studies referred above, prompt us to be very prudent in indicating some systematic links between the sources of funding and the patent behavior. The institutional and legal frames related to the concerned activities are certainly more important than the origins of the funds.

Table III
Estimation of Model 2 with decomposed contractual funding. All are zero inflated negative binomial estimations but the second one which is a negative binomial estimation

Indep. Var./Dep. Var.	Pat	Pat^own	Pat^not_own1	Pat^not_own2
Constant	−3.21 (2.62)	−10.25 (11.51)	−16.65 (6.8)**	−2.55 (2.89)
Cont ^ nat	0.00 (0.04)	−0.23 (0.38)	−0.06 (0.12)	0.03 (0.05)
Cont ^ reg	0.03 (0.03)	0.24 (0.14)*	−0.05 (0.13)	0.02 (0.04)
Cont ^ eur	−0.01 (0.03)	0.08 (0.19)	−0.05 (0.11)	−0.02 (0.04)
Cont ^ ind	0.05 (0.03)*	0.14 (0.13)	0.15 (0.07)**	0.03 (0.04)
Cont ^ prc	0.03 (0.03)	0.09 (0.14)	0.01 (0.06)	0.01 (0.03)
Cont ^ as	0.03 (0.05)	0.06 (0.16)	−0.13 (0.15)	0.02 (0.05)
Dcont	0.34 (0.21)*	1.58 (0.82)*	0.32 (1.36)	0.24 (0.22)
Size	0.24 (0.07)***	0.6 (0.45)	1.81 (0.41)***	0.22 (0.08)***
Disc				
Bio	1.09 (0.23)***	4.71 (1.61)***	5.34 (1.00)***	0.24 (0.27)
Che	0.29 (0.23)	1.45 (1.92)	2.78 (1.05)***	0.2 (0.23)
Gen	1.04 (0.23)***	4.37 (1.53)***	3.46 (1.30)***	0.53 (0.25)**
Med	0.08 (0.24)	3.12 (1.22)**	1.78 (1.22)	−0.3 (0.33)
Neu	−0.56 (0.43)	2.47 (2)	0.71 (1.49)	−0.8 (0.59)
Ph	0.76 (0.29)***	1.51 (2.28)	8.1 (1.60)***	0.56 (0.31)*
Inst				
Ea	0.46 (0.26)*	1.61 (1.15)	1.89 (0.65)***	0.83 (0.66)
Je	−0.05 (0.51)			
Uins	0.72 (0.31)**	−0.13 (1.92)	−0.89 (1.57)	1.65 (0.90)*
Umr	0.61 (0.24)***	1.91 (1.44)	−1.80 (0.65)***	1.06 (0.85)
Upr	0.78 (0.29)***	0.41 (1.13)	−1.00 (0.95)	1.51 (0.90)*
Time	0.02 (0.03)	0.01 (0.12)	0.10 (0.07)	0.00 (0.03)
δ	0.68 (0.26)***	2.27 (1.39)	0.41 (0.32)	0.80 (0.33)**
þ	−1.45 (0.56)**		0.91 (0.31)***	−2.07 (1.24)*
Log likelihood	−598.81	−152.19	−276.62	−384.76
Chi-squared		17.30***		
Vuong statistic	3.01		5.31	2.37

Standard errors are in brackets. The number of asterisks (one, two or three) denotes the level of significance of the coefficients (10, 5 or 1%, respectively). δ and þ are technical parameters to control for the presence of overdispersion (negative binomial model) and the excess of zeros (zero inflated model.)

The sign and significance of the other coefficients remain the same as in Model 1, therefore pointing out the consistency of the results. The only changes are some significance of the positive coefficient of *upr* regarding patents of the second circle of inventors (*pat^not_own2z*), which adds evidence that more prestigious institutions concentrate in this type of patents, the CNRS or INSERM being the owner of the patents.

5. Conclusion

We have proposed various estimations of academic patent production using a panel dataset of laboratories belonging to Louis Pasteur University over the period 1993–2000. We found that aggregated contractual funding (i.e. both public and private contractual funding) has a significant and positive impact on the generation of patents while controlling for laboratory differences (size, discipline, institutional status). Since we took logarithms to measure contractual funding, such coefficients can be interpreted as elasticities. Being significantly below one, we thus find evidence of decreasing returns to contractual funding.

When we disaggregated the different sources of funding, we observed more complex reactions to contractual funding, e.g. for university non-owned patents invented by the first circle of inventors, only industrial funds matter. The external funding from companies is stimulated by having access to the property rights on the results. A better understanding of the patent behavior of European universities should imply a careful look into the legal and institutional rules that regulate the links between university and external industrial partners. It would be especially interesting to compare the relation between the research sponsored by industry and the propensity to patent in Europe and in the US.

Finally, our results highlight the importance to control for disciplinary and institutional differences, since they significantly affect the production of the different kinds of ULP patents. Therefore, we provide a first set of evidence on the link between disciplines and ownership and between institutions and circles of inventors of ULP patents. Moreover, this implicitly supports the use of laboratories as a unit of analysis to estimate the returns of contractual funding on patents.

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Notes

1. We use a broad notion of contractual funding, which includes not only funds from multilateral agreements but also from public calls for tenders, i.e. external funds, obtained through specific processes of competition, in particular private or public research programmes.
2. Thereby we are departing from other studies on academic patenting to the notable exception of Foltz *et al.* (2001) who study US universities patenting.
3. In France the revenues from patenting activity are shared equally among the inventor, the laboratory and the university.
4. However, it may also have counter-productive impacts: Siegel *et al.* (2003), using the results of a survey of managers and scientists, report that one of the main objectives of ILO is the protection of property rights, although they tend to be "inflexible and conservative" when they negotiate agreements and licenses.
5. They control for size, but they do not find it significant. They are also interested in the methodological issue of finding an appropriate instrumental variable to avoid endogeneity problems and omitted input bias. They conclude that using alumni representation on US congressional appropriation committees improves the fit of the model.
6. There have been some studies about university patents in Europe: in a Swedish university (Wallmark, 1997), on the German case (Meyer-Krahmer and Schmoch, 1998), in Italy (Piccaluga, 2001; Balconi *et al.*, 2002) and in a comparison between France, Italy and Spain (Cesaroni and Piccaluga, 2002). However, none of them apply econometric methods. An exception is Azagra *et al.* (2003), on a case study of a Spanish university.
7. We are using the data of the evaluation process which occurred in 1996. Since there is usually in France a very low turnover in teaching and research staff, we assume that our dataset allows for a large coverage in terms of teaching and research staff populations for the 1993–2000 period.
8. Therefore, it does not include other financial 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.
9. Nevertheless, it should be noted that due to institutional arrangements between the University and both the CNRS and INSERM, research units research units which contracts we miss are limited to only a few of the ones supported by the CNRS and INSERM and are well identified. That statement supports the treatment of that data measurement issue through the dummy *Dcont*.
10. We also tried with time dummies instead of a time trend, but results were identical.
11. For technical details, see Greene (2003), section 21.9.
12. In every case, we will use pooled panel technique.
13. The volatility of the sign of the coefficient of *umr* is particularly striking. Although their inventors significantly patent more on average than *others*, those in the first circle significantly patent less through industry (*pat^not_own1*). The same occurs with *upr* but the effects are not significant.
14. Since only a few *jeunes equipes* patent, when we differentiate between types of patents (columns 2, 3 and 4 of Table III), the variable *je* caused collinearity problems. This variable has thus been dropped from these estimations.

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