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University IPRs and knowledge transfer: is university ownership more efficient?

Gustavo A. Crespi[a], Aldo Geuna[b,c,d], Önder Nomaler[e] and Bart Verspagen[f,g]*

[a]*Science and Technology Division, Inter-American Development Bank (IDB), Washington, DC, USA;* [b]*Department of Economics S. Cognetti de Martiis, University of Torino, Torino, Italy;* [c]*Collegio Carlo Alberto, Torino, Italy;* [d]*Grenoble Ecole de Management, Grenoble, France;* [e]*Department of Industrial Engineering & Innovation Sciences, Eindhoven University of Technology, Eindhoven, The Netherlands;* [f]*Department of Economics & UNU-MERIT, Maastricht University, Maastricht, The Netherlands;* [g]*Centre for Technology, Innovation and Culture (TIK), University of Oslo, Oslo, Norway*

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This paper addresses an issue that has been largely ignored so far in the empirical literature on the role of patents in university–industry knowledge transfer: does it matter who owns the patents on university research? We observe that especially in Europe, many patents in which university researchers are listed as inventors are not owned by the university. From a literature review, we conclude that private ownership of university patents may reduce the efficiency of the knowledge transfer process. This hypothesis is put to an empirical test, using data on patents in six European countries. Specifically, we assess whether *university-owned* patents (in Europe) are more often applied, and/or more economically valuable, than *university-invented* (but not-owned) patents. Our results indicate that, after correcting for observable patent characteristics, there are only very small differences between *university-owned* and *university-invented* patents in terms of their rate of commercialization or economic value.

Keywords: university patenting; public–private technology transfer; European universities

JEL Classification: O3; I28

1. Introduction

The role of universities in the production of economically useful knowledge has received much attention in recent years, from both academics and policymakers (e.g., European Commission 2003; OECD 2003). Perhaps one of the most controversial issues in this debate is the role of patents (see, among others, Verspagen (2006) for an overview of the literature). The so-called Bayh–Dole Act in the USA stimulates universities to patent the results of their research, something that is, according to some (Heller 1998), against the open nature of science and therefore affects the productivity of basic research in a negative way. The

*Corresponding author. Email: b.verspagen@maastrichtuniversity.nl

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proponents of Bayh–Dole, on the other hand, argue that in order to interest firms in follow-up research needed to turn basic research results into economically useful inventions, patents on the basic knowledge must ensure that also the follow-up research can be appropriated. Much of the debate on Bayh–Dole and similar policies in other parts of the world has focused exactly on this controversy, i.e., whether or not the results of university research should be patented.

Many who have commented on the European data on university patenting have concluded that Europe is lagging behind the USA; i.e., European universities patent too few of their research results (Porter 2001; OECD 2003). However, careful scrutiny of the data reveals that this conclusion may be too hasty. In Europe, many research projects in which university researchers work with firms lead to patents that are owned by firms rather than by the universities. This does not show up in the statistics based on patent databases, since the affiliation of researchers is not given, and 'university patents' are defined exclusively as 'patents owned by universities' (Geuna and Nesta 2006). Below, we provide a systematic comparison between the extent of university patenting in the USA and in Europe, based on a wider definition of 'university patents', which also includes patents not owned by universities, but in which university researchers appear as inventors.

However, beyond the mere quantitative comparison of how frequent university patenting is in the USA and Europe, this issue raises a deeper question, i.e., whether it makes any difference for the efficiency of technology transfer who owns the patent on university research. This question is the topic of the analysis in this paper. Specifically, we ask whether ownership of patents on university research has any impact on either the rate at which the knowledge in the patent is applied commercially, or what is the economic value of the patent. We will approach this question in an empirical way, by exploiting data on almost 500 university patents (with mixed ownership) across six European countries.

Both in terms of our statistical methodology and in terms of the theoretical hypotheses that we will formulate, an additional question that follows from our main research question is important. This is the question: what determines whether a patent is owned by the university, by a firm, or personally by the inventor. The answer to this question depends partly on the legal context of the countries that we analyse, but there are also economic factors that have an impact on ownership. Below, we will provide a brief overview of the theoretical literature that addresses this question, as well as of the literature that analyses the impact of ownership on the efficiency of knowledge transfer.

At the outset of our analysis, we feel the need to also point to two important limitations of our project. The first is that while we focus on the role of patenting in knowledge transfer from universities to firms, in fact we ignore other channels of knowledge transfer that are probably more important in a quantitative way, such as contract research or researchers' mobility (Bekkers and Bodas de Araujo Freitas 2008). The second is that our empirical analysis cannot address the role of Technology Transfer Offices (TTOs). The patent data that we use refer to a period (the mid- and late-1990s) in which TTOs were simply not very important, if existing at all, in European countries, except for the UK, which is one of our six countries.[1] The database does not identify the role of TTOs in any way, and therefore we cannot address any of the recent literature that has analysed the role of TTOs in university–industry knowledge transfer (Debackere and Veugelers 2005; Macho-Stadler, Perez Castrillo, and Veugelers 2007; Siegel, Veugelers, and Wright 2007). We will, however, come back to the role of TTOs in our conclusions.

The answer to our research question about the impact of ownership on university–industry knowledge transfer has policy relevance. In particular, the theoretical research that we will review below suggests that firm ownership of patents that result from university research is inefficient. Aghion and Tirole (1994) suggest that private ownership of university patents is a form of market failure because university researchers do not have an incentive to make a high-quality contribution. Hellman (2007) argues that private ownership may be associated with less efficient searching for commercial partners on the part of the university and its researchers. As far as we know, these theoretical assertions have so far not been tested in empirical work on university patenting. If they were true, the implication would be that indeed the 'European mode' of university patenting (i.e., leaving ownership to private partners) is inefficient, and therefore a possible cause for the perceived lag of Europe in applying university knowledge commercially (Dosi, Llerena, and Labini 2006).

The paper is organized as follows. In Section 2, we review the empirical and theoretical literature on intellectual property rights (IPR) ownership in the context of public–private research joint ventures and present our hypotheses. The data sources and a descriptive overview of ownership of university patents are presented in the Section 3, which also includes a systematic comparison of US and European university involvement in patenting, based on our broader definition including non-university-owned patents. Section 4 briefly presents the statistical methodology, and some descriptive statistics. Section 5 presents the results. Section 6 discusses the results in relation to current policy actions.

2. University IPR ownership and technology transfer

The observation that patents in which university researchers are involved are owned by private parties has been dubbed 'an empirical anomaly' (Thursby, Fuller, and Thursby 2007), and 'bypassing' (of universities by their faculty, Markman, Gianiodis, and Phan (2008)). These somewhat negative terms seem to reflect mainly on the US post-Bayh–Dole context, in which ownership of the IPR of university inventions is clearly in the hands of the university. In the European context, the situation was not as clear, certainly not in the period in which the patents in our sample were applied for (the early and mid-1990s). Some countries in Europe (Austria, Denmark, Finland, Germany, and Norway) traditionally had the so-called professor privilege, which gives university employees the IPR to their inventions. Most of these countries recently changed their legislation, assigning ownership to the university, but in the country in our sample to which this refers (Germany), this happened too late to be relevant for the patents in our dataset. In other countries in Europe, in fact, all countries in our dataset except Germany, university ownership was already the legal default, but this was usually weakly enforced, thereby de facto leaving the decision on ownership to be negotiated.

In such a context, the decision of ownership of university inventions becomes motivated by economic rather than legal factors. The literature has identified several factors that influence this decision. Markman, Gianiodis, and Phan (2008) present an empirical analysis of the issue of 'by-passing' at the university-level, and hence the factors that they analyse mostly refer to levels of aggregation that are above the individual invention level. They distinguish four categories of factors influencing the ownership decision: organizational factors, agency factors, resource factors and entrepreneurial factors. Under organizational factors, they discuss issues related to the way the university (and the TTO) organizes the process of invention disclosure and the subsequent patenting track. They mostly focus on the way the university TTOs is embedded in the organization, and pose the hypothesis that university ownership is more likely when the TTO is more autonomous. The group of agency factors encompasses factors related to incentives, such as agreements on royalties, etc. The hypothesis formulated by Markman, Gianiodis, and Phan is that when universities provide contingent payment schemes for patented inventions, this makes university ownership more likely. The category of resource factors include the way in which the research process leading to the invention is financed, but also what is the (expected) value of the invention. More valuable inventions are more likely to be owned outside the university. Finally, under entrepreneurial factors, the general climate of interaction between university inventors and businesses is considered. The hypothesis is that greater interaction ('entrepreneurial activity') will lead to more ownership outside the university.

Jensen, Thursby, and Thursby (2006) provide a quantitative model of patent ownership that focuses on factors at a lower level of aggregation, i.e., mostly at the level of the individual research project and the inventors that are active in it. The model does not look directly at the decision on ownership assignment, but instead models consulting of university researchers for a private firm. In the empirical analysis that follows the model, private ownership of a university patent is considered as an indicator of consulting; i.e., those factors that the model predicts will positively influence consulting are assumed to also positively influence private ownership. The two factors in the empirical analysis are researchers' quality, which is indicated by publications and citations to publications, and availability of research funding by non-profit funding organizations, which is expected to be negatively related to consulting.

Hellman (2007) provides a model that is broadly set in the same context as Jensen, Thursby, and Thursby (2006), but considers the ownership issue in a more direct way. He considers a two-stage research process in which a university-employed scientist first develops an 'idea', and then seeks out a firm to develop it into a commercial project. This search process may either take place through the university's TTO, in which case the patents will be owned by the university, or may be done by the researcher himself/herself, in which case the patent is left to the firm. The assumption is that for a given expenditure, the TTO's probability of finding a match is higher than what the scientist would achieve on his/her own. Hence, the involvement of the TTO increases the efficiency of the search process. However, if the TTO is not involved, the researcher may command a higher fee from the firm, which provides an incentive to bypass the TTO. Thus, the scientist faces a trade-off between disclosure, which raises the probability of commercialization but lowers the pay-off from it, and non-disclosure, which lowers the probability of commercialization but raises the pay-off from it. When the search costs advantage of the TTO is not particularly strong (e.g., when the scientist is well embedded in a strong network of private firms, which reinforces the 'entrepreneurial factor' from Markman, Gianiodis, and Phan), the negative effects of disclosure outweigh the positive from the scientist's perspective. In such cases, the scientist will seek out a firm on her own, and ownership is left to this firm.

Aghion and Tirole (1994) consider the issue of patent ownership in the setting of a joint research project between a private firm and a university. Both parties need to invest in the project, but due to uncertainty, the contract for the research project is incomplete. It specifies only the attribution of the property right (who owns the patent), the licence fee that the university obtains in the case in which the patent is assigned to the firm, and the level of the firm's investment. If the firm owns the invention, the university does not share in the profits. Instead, it is paid a pre-bargained fee for its research efforts. On the other hand, if the university owns the invention, both parties share the pay-off through a licensing fee levied by the university. The university and the firm bargain *ex ante* over ownership of the expected invention, taking into account these (expected) benefits.

Due to the incompleteness of the research contract, the firm does not have the means to control whether or not the university is making the maximum effort. Thus, if the university does not own the invention, its best strategy is to contribute minimal research effort (since the effort does not influence the fee), and this leads to a less valuable invention.

The alternative for the firm is to share pay-off, which can be accomplished by leaving the patent in university ownership. The firm must compare this shared pay-off with maximum effort from the university with a non-shared pay-off, but minimal university effort. In this situation, the higher the marginal impact of the university effort, the greater the willingness of the firm to leave ownership of the invention to the university.

Conti (2008) presents a similar model, in which a basic research project can subsequently be applied to a number of application fields. Although this model considers firm ownership of patents as the only outcome, it is interesting because it introduces an additional factor related to ownership. Her model focuses on explaining how broad the patent will be. The university decides how broad a patent it wants to grant to the firm (i.e., how many application fields will be included in the patent). This decision depends mainly on the relative marginal productivities of research of the firm and the university researcher. *Ceteris paribus*, if the firm's contribution becomes more important, the university researcher is willing to grant a broader range of application. In terms of our question, i.e., what determines ownership, this readily extends to the hypothesis that the larger the marginal contribution of the firm to the joint project, the larger the probability that the firm owns the patents, which is similar to Aghion and Tirole (1994).

Summarizing, the literature identifies a range of factors that influence whether a university patent will be owned by the university or by a private party (firm) interested in the invention. The ones that are most relevant to our analysis relate to low levels of aggregation, i.e., to the researcher and project level. Based on the survey, we expect that researcher quality, or more general, researcher characteristics, and the relative contribution of the firm and the university to the project are the most important factors.

Now that the factors that determine ownership of university patents have been briefly surveyed; we turn to the question of the effects of ownership on technology transfer, i.e., on the rate of commercial application and patent value. This is a question that is analysed less frequently than the question, what determines ownership. Two contributions stand out; however, which are the Hellman (2007) and Aghion and Tirole (1994) models that were already introduced above.

Although Hellman (2007) does not undertake a detailed welfare analysis of the case of university ownership, it is clear that there may be a negative impact on the social value of university research if the scientist decides not to disclose the invention. Involvement of the TTO will increase the probability of commercialization because of its lower search costs. Thus, in the context of the Hellman model, private ownership of patents based on university research is an indication of a less efficient matching process, and hence lowers the probability of commercial application of the patent. This leads to the *hypothesis* (investigated below) that university ownership of a patent on research in which that university was involved increases the probability of commercialization of the invention (naturally, commercialization will then take place in an indirect way, e.g., by licensing out the patent).

In Aghion and Tirole (1994), non-university ownership may be associated with market failure, in the sense that the value of the invention that is produced as a result of the research joint venture is suboptimal. This result can only arise if the firm owns the patent; i.e., market failure is asymmetric. To see how this works, recall that university ownership raises the effort of the university and thereby also raises the value of the invention. However, it reduces the share of the total value that accrues to the firm. Hence, the firm will only leave ownership to the university if the increase in value is large, i.e., so large that it compensates for the fact that it loses a share of the total value.

Note that the Aghion and Tirole model mainly argues about market failure based on the economic value of the patent, not, as in the case of Hellman (2007), the probability of commercial application. Hence, we consider these two contributions to be complementary. On the basis of Aghion and Tirole's work, we *hypothesize* that, on average and *ceteris paribus*, the economic value of university-owned patents will be higher than for university-invented patents owned by firms.

3. Ownership of academic patents in Europe and the USA

In recent years, scholars have realized that the number of *university-owned* patents, usually collected by national technology transfer associations and statistical agencies, is an underestimation of the real inventive activities of universities. This has been highlighted especially for Europe (Geuna and Nesta 2003; Meyer 2003; Balconi, Breschi, and Lissoni 2004; for a recent attempt to systematize the European evidence see Lissoni et al. (2007)) and only more recently for the USA (Thursby and Thursby 2005; Markman, Gianiodis, and Phan 2008). We will try to provide a systematic comparison of the available evidence for Europe and the USA.

For our empirical analysis, we rely on the Patval survey. For a full description of the survey sample, methodology, and a preliminary analysis of the response see Giuri et al. (2007). The survey was addressed at inventors listed on (granted) European patents with a priority date in the period 1993–1997, in six European countries: Germany, France, Italy, the Netherlands, Spain, and the UK. These six countries were chosen because of their size and relative importance in the European Patent Office (EPO) database; they accounted for about 88% of granted EPO patents whose first inventor has an address in of the EU-15 countries (about 42% of the total EPO). The survey was carried out in the July 2003–April 2004 period. For the six countries considered, the total number of EPO patents with priority dates between 1993 and 1997 was 49,078. Where there were several inventors, we first tried to contact the first inventor. If no response was received, the second inventor was contacted, and so on until a response was obtained. Most countries concentrated on a sub-sample of patents but some sent the questionnaire to all patent inventors. We contacted 27,531 patent inventors and obtained responses relating to 9017 patents. This equates to a 33% response rate (at the inventor level) and represents 18% of all granted EPO patents with a priority date between 1993 and 1997. The final sample of 9017 patents shows no bias in terms of patent quality (citations received and opposition) or patent technology classes (Gambardella, Harhoff, and Verspagen 2008).

On the basis of a question that asked where the inventor was employed at the time of the invention, we were able identify 433 patents in which at least one of the inventors was employed by a university (we label these '*university patents*'). They represent 4.8% of all observations. Gambardella, Harhoff, and Verspagen (2005) have constructed sampling weights, defined as the inverse probability of a patent being in the set of 9017 observations. These weights are based on a comparison of the responses with all granted patents with a similar priority date in the six countries, on the basis of observable characteristics in the patent document (such as inventor country, priority date, technology class), as well as citations received. These weights enable us to assess the representativeness of the 433 university patents relative to the total sample, i.e., to determine whether or not the inventors of university patents are more or less likely to respond. The results of this calculation show that we have a very small overrepresentation of university patents: the share of our 433 cases in the sum of the sampling weights over the complete ($n = 9017$) sample is 4.93%, while in terms of the number of observations, their share is 4.80% (433/9017).[2] In the remainder of this paper, we ignore this, and proceed as if our university patents sample is representative of the larger universe in the six countries.

Table 1 presents, for each country in the sample, the total number of patents, and breaks down ownership into university or non-university. *University-owned* patents are those patents that have a university assignee, while *university-invented* patents are those patents that have at least one university inventor but they are not owned by a university. What the table brings out very clearly is that the large majority of patents in which university inventors were involved is not owned by universities.[3] In all countries except Spain, the fraction of *university-owned* patents in *university patents* is far below half.

Although this paper focuses on academic patents, the intricacies of the university system in certain EU countries where Public Research Organizations (PROs) overlap at least in part with universities, requires us also to consider PRO-patents (those patents that have at least one PRO inventor). France (CNRS), Italy (CNR) and Germany (Fraunhofer) are examples. The second part of Table 1 provides this information. As expected, countries with important PRO infrastructure such as France and the Netherlands have a significant number of *PRO patents*, less so the UK, where most of the research is carried out in universities. France is the only country where the number of PRO patents in the sample is larger than the number of university patents.

Interestingly, compared with the situation in universities, the case of *PRO patents* is less clear-cut in terms of ownership. Although in the data for all countries together, the number of *invented* PRO patents is still the majority, this is the result of opposite situations in various countries (probably dependent on different institutional and legal configuration). In the cases of Germany, the Netherlands and Spain, *PRO-owned* patents are more frequent than *PRO-invented* patents; the contrary applies to the cases of France, Italy and the UK.[4]

Table 2 analyses in more detail the ownership structure of *invented* patents. About 4/5 of the *university-invented* patents are owned by companies, 10% are assigned to governmental offices of various kinds – PROs and other public private partnerships (PPPs) – and 9% to individuals (mostly in the case of Germany and Italy).[5] Companies play a (slightly) less

Table 1. Ownership of European university/PRO patents.

	Germany	Italy	France	UK	Spain	Netherlands	Total
Number of *university patents*	108	50	60	139	17	59	433
University-owned patents	4	2	7	45	9	12	79
	4%	4%	12%	32%	53%	20%	18%
University-invented patents	104	48	53	94	8	47	354
	96%	96%	88%	68%	47%	80%	82%
Number of *PRO patents*	62	13	77	37	7	40	236
PRO-owned patents	45	4	24	0	4	23	100
	73%	31%	31%		57%	57.5%	42%
PRO-invented patents	17	9	53	37	3	17	136
	17%	69%	69%	100%	43%	42.5%	58%

Table 2. Ownership of European university-/PRO-invented patents.

	Ownership	Total sample
University-invented patents	Companies	287 (81%)
	Government, PRO, PPP	36 (10%)
	Individuals	31 (9%)
PRO-invented patents	Companies	81 (60%)
	Government, Univ., PPP	43 (31%)
	Individuals	12 (9%)

dominant role in the case of *PRO-invented* patents, accounting for about 60% of them. Apparently, PROs are more often more directly linked to government results in a higher share of ownership by governmental offices (about 30%). A particular case is military research; 17% of the *PRO-invented* patents were assigned to the UK Secretary of State for Defence (UK), underlying the important role of military research in the UK. Finally, individuals account for 9%, as in the case of university patents.

What does this imply in terms of the differences in the patent outputs of US and European universities? Most of the (European) policy literature (e.g., European Commission 2003; OECD 2003) claims that there is a major gap between US and European universities in terms of involvement in patenting. Our data suggest that European universities, or at least their researchers, patent more than is generally assumed, but we need a benchmark to enable comparison with the US situation.

According to National Science Foundation (2004), academic patents accounted for between 1.9% and 4.3% of United States Patent and Trademark Office (USPTO) patents in 1993–1997, depending whether all USPTO patents or only those assigned to US organizations (private and non-profit) are considered. Given the absence of a response bias for university patents in our sample, it is clear that European universities have a (broadly) similar share as compared with US universities. Why do our results differ in such a dramatic way compared with the commonly accepted policy view of a technologically low-performing higher education system in Europe? The most important reason is that official data take only into account *university-owned* patents, and therefore underestimate in a macroscopic way the activity of European universities.

Thursby, Fuller, and Thursby (2007) show that this phenomenon (firms owning patents to university research) also occurs in the (post Bayh–Dole) USA. In their US sample, 66% of all university patents were owned by universities, clearly a higher percentage than revealed by the European data. Thursby, Fuller, and Thursby (2007) have put together information at the inventor level controlling for ownership for 87 research intensive universities accounting for about 5800 patents granted in the period 1990s until 2004. Table 3 presents our elaboration of their data (similar result can be obtained for only those patents granted in the late 1990s period that better overlaps with our sample).

Although we acknowledge that the two samples may be not perfectly comparable, the first striking observation is that while in the USA, about 2/3 of *university patents* are owned by the university that employed one of the inventors, in Europe, university ownerships accounts for less than 1/5. This result seems to point to the existence of two different models of university technology transfer. The American model is mainly based on the university owning the rights to the discovery made by one of its academic employees; on the basis of this right, the university commercializes the discovery via the TTO. Instead, the European model of academic technology transfer is mainly based on a direct transfer of property rights from the academic inventor (or university) to the private sector (usually a

Table 3. Ownership of US university patents.

	Share of total academic patents	Ownership of *university-invented* patents
Total number of *university patents*	5811	
# *University-owned* patents	66.5%	
# *University-invented* patents	33.5%	Firms 77.6% Unassigned 16.7% US federal government 6.7%

Source: Author elaboration of data from Thursby, Fuller, and Thursby (2007).

large firm), with only a minor role for university ownership and TTOs activity in licensing or spin-offs.

One may argue that the figures presented here clearly show the incentive creation effect that the Bayh–Dole Act had in the US system. But does this lead to a much higher academic patents production in the US system when compared with Europe? If we adjust the data for the USA taking into account that the official statistics underestimate about 1/3 of the number of *university patents* (generalizing the result of Table 3 that about 1/3 of patents had an academic inventor but were not owned by the university), and we recalculate the two shares of academic patents on US-PTO patents present above, we would end up with a bracket 2.9–6.5% (depending on whether US university patents are expressed as a share of total USPTO-issued patents, or only those assigned to US residents). Anecdotal evidence suggests that the share of foreign-residents in holding domestic patents is higher in the USA than in Europe, and hence the upper end of the bracket (6.5%) is probably a better benchmark than the lower bracket. Comparing the upper bracket value with the 4.8% from our sample suggests that university-owned patents in the USA and Europe are of roughly comparable orders of magnitude, with Europe perhaps lagging slightly, but not by as much as the official statistics would seem to indicate.

To understand the relative importance of this difference, it is worth remembering (Table 2 above) that a significant part of the European high quality science system is institutionally organized in the various national PROs (such as the Max Plank Institute, CNRS, CNR, etc.) without a clear counterpart in the USA. Thus, a sizable portion of European scientific activity that generates patents is situated outside the university system in the PROs (Cesaroni and Piccaluga 2005); therefore some of the difference between US and European academic patent output could also be attributed to the different institutional set up.

These back-of-the-envelope calculations make the point that once the available data are adjusted for the ownership structure, thus taking into account the different university technology transfer models, and for the different institutional set up of science, it is not so clear that the US system is outperforming the European system. US universities may have had more patents than European universities in absolute terms; however they did not have a much higher share of national patents.

4. Methodology and descriptive statistics

Our research question addresses the impact of ownership of university patents on the efficiency of technology transfer, in particular on the rate of commercial application on patents and the commercial value of patents. We will approach this question using two different statistical techniques. The first estimates two econometric models that take the rate of commercialization and the economic value as the dependent variables. The explanatory variables include a range of factors possibly influencing commercialization or value, including the variable university ownership. The control variables will include our proxies for the various factors that emerged in the above literature review as influences on the university ownership variable. In this way, we aim to disentangle the various influences on commercialization and value, so as to enable us to identify the university ownership effect separately. If the university ownership variable remains significant in the presence of these controls, we take it as an indication of a positive impact of university ownership on the efficiency of technology transfer.

The second technique starts with the identification of the university-owned patents as a sample of so-called treated patents (the 'treatment' being university ownership). A control sample of 'non-treated' (*university-invented*) patents is then constructed, based on the idea that the control group should be as similar as possible to the treated sample except, of course, in terms of treatment (university ownership). In order to determine the control group, we will first estimate a probability model that explains the treatment (university ownership), and take the predictions of this equation to match treated patents with those that were not treated, but had a similar probability of being treated. Given the adequacy of this control group, we can apply a *t*-test for differences in the commercialization and value variable means, to test our research hypotheses.

Table 4. Variable definitions.

Block	Variable	Definition
Impact	Patent used	Dummy, 1 if the patent was used commercially in any way (maximum of 3 dummies below)
	Licensed	Dummy, 1 if applicant/owner has licensed out the patent
	Start-up	Dummy 1, if the patent was used to start a new firm
	Expected value	Value of invention as estimated ex post by inventor, based on interval responses. We took the natural log of the mean value of each interval, except the right border of the lowest interval and the left border of the top interval
Inventor background	Age	Age of inventor at time of survey
	Graduation	Year of graduation for most recent degree
	Male	Dummy variable, 1 if inventor is male, 0 if female
	Experience	Number of years between year of graduation and entering the job in which the patent was invented
	Tenure	Number of years in the job when the patent was invented
	Postgraduate degree	Dummy, 1 if inventor has a postgraduate degree
	EPO patent applications	Total number of patent applications at EPO by the inventor (ln)
Invention background	R&D total costs	Inventor estimate of total R&D costs leading to patent (1000 euro, ln)
	Man-months	No. of man-months on research leading to patent, based on interval responses, using mean of intervals
	Family	Dummy, whether patent is part of a family (i.e., a set of technically interrelated patents)
	No. words claim	No. of words in the claims (ln)
	No. IPC 4-digit	No. of 4-digit IPC classes (ln)
	No. inventors	No. of inventors listed
	Multiple applicants	Dummy, if there is more than 1 applicant
	Cooperation	Dummy, if non-university inventor(s) were involved
	FormCol	Dummy, if there was a formal collaboration agreement
Technology effects	ISI-ElEng	Dummy, 1 for electrical engineering
	ISI_Instr	Dummy, 1 for instruments
	ISI_ChePha	Dummy, 1 for chemicals/pharmaceuticals
	ISI_PrEng	Dummy, 1 for precision engineering
	ISI_MechEng	Dummy, 1 for mechanical engineering
Country effects	UK	Country dummy UK
	DE	Country dummy Germany
	IT	Country dummy Italy
	ES	Country dummy Spain
	NL	Country dummy Netherlands
	FR	Country dummy France

Before we present the results of these methods, we briefly look at some more descriptive statistics on the variables that will be used. Table 4 presents all variables in the analysis. For the dependents, three separate variables are used to capture the rate of commercial application of the patents, and one to capture economic value. The three variables related to commercial application are dummy variables with the value 1 if the respondent indicated patent use. Two of these variables measure particular application modes: either licensing-out of the patent, or using the patent for a start-up company. The third application-related variable is called *Patent used*, and is a summary-variable. It takes value 1 if any application mode has been used at all. Note that there is a third specific application mode in addition to licensing and start-up. This is commercial use of the patent by the applicant itself. Since this is not very relevant for university-owned patents, we do not analyse this application mode separately (but it is included in the overall variable *Patent used*).

To measure patent value, the PatVal questionnaire also asked respondents to provide a (subjective) evaluation of the value of the patents. The responses were structured in 10 asymmetric intervals ranging from less than €30,000 to more than €300 million.[6] This variable is interval-scaled.

The independent variables must then proxy for the factors that were identified in the literature review of Section 2. As our data refer to individual inventions, we mostly have control variables at this level too, or at the inventor level (as the survey was aimed at inventors).[7] Factors at the organization (university of firm) level are poorly represented in our dataset, and hence cannot be included. Besides technology field and country dummies, there are two main categories of variables: those related to the background of the inventor, and those related to the background of the invention. Table 5 presents a comparison of the means of all variables, between *university-owned* and *university-invented* patents. We will briefly introduce the variables in a discussion of this comparison.

The country effects, which are included to take into account institutional characteristics such as differences in the legal system, show that there are major differences between ownership modes in the distribution of patents across the different countries, in line with the results presented in Table 1. The UK and Spain account for a significantly higher fraction of patents in the university-owned group than in the university-invented group, while in Italy and Germany, the situation is reversed. For France and the Netherlands, we do not reject the null hypothesis of a balanced proportion of both types of patents. The results for technology effects are more balanced. The only technology class where we can reject the null hypothesis of equal shares in both groups is Instruments, but this difference is significant only at the 10% level.

The pattern in the distribution of inventors' characteristics across both sub samples of patents is fairly balanced. There are no significant differences between the samples for inventor's *Age*, for *Graduation* (which is the year in which the last degree was obtained, and hence a sort of measure for 'professional age'), *Experience* (which is short for the number of years of experience before the job in which the patent was invented) and the *Male* dummy. Two variables in the inventor background category that appear as significantly different between the ownership samples are *Tenure* (number of years in the job where the patent was invented) and the number of *EPO patent applications* (a measure for previous patenting experience). In both these cases, the mean of these variables is higher for the non-university-owned group. If we take these variables as a measure of 'researcher quality', these descriptives are against the hypothesis raised by Jensen, Thursby, and Thursby (2006), who argue that researcher quality should influence consulting (firm ownership) in a negative way. Their hypothesis about researcher quality is 'confirmed' by the final variable in the inventor background category, *Postgraduate degree*, which is a dummy for whether or not the inventor

Table 5. Patent characteristics in each sub-sample.

Block	Variable	University-owned	University-invented	Std	*t*-Value	*p*-Value	Number of observations	Significance
Impact	Patent used (0/1)	0.709	0.548	0.061	−2.632	0.009	433	***
	Licensed (0/1)	0.557	0.150	0.048	−8.456	0.000	433	***
	Start-up (0/1)	0.228	0.082	0.038	−3.825	0.000	433	***
	No. of forward citations	0.114	0.500	0.138	2.792	0.006	433	***
	Value (ln)	6.226	5.962	0.218	−1.212	0.226	433	
Inventor background	Age	45.6	46.5	1.361	0.691	0.490	433	
	Graduation	1978.9	1977.7	1.366	−0.936	0.350	433	
	Experience	5.722	5.394	0.828	−0.395	0.693	433	
	Tenure	12.418	15.093	1.275	2.099	0.036	433	**
	Male	0.937	0.952	0.027	0.558	0.577	433	
	Postgraduate degree	0.899	0.808	0.047	−1.923	0.055	433	*
	EPO patent applications	0.290	0.646	0.076	4.709	0.000	433	***
Invention background	R&D total costs	11.181	10.961	0.216	−1.017	0.310	433	
	Man-months	5.411	4.569	0.219	−3.847	0.000	433	***
	Family	0.468	0.503	0.062	0.560	0.576	433	
	No. words claim (ln)	4.682	4.758	0.087	0.873	0.383	433	
	No. IPC 4-digit (ln)	0.419	0.343	0.056	−1.353	0.177	433	
	No. inventors	0.869	1.094	0.066	3.436	0.001	433	***
	Multiple applicants (0/1)	0.152	0.085	0.037	−1.826	0.069	433	*
	Cooperation (0/1)	0.152	0.565	0.059	6.991	0.000	433	***
	FormCol (0/1)	0.380	0.723	0.057	6.057	0.000	433	***
Technology effects	ISI-ElEng (0/1)	0.165	0.138	0.044	−0.599	0.550	433	
	ISI_Instr (0/1)	0.291	0.192	0.051	−1.958	0.051	433	*
	ISI_ChePha (0/1)	0.304	0.367	0.596	1.064	0.288	433	
	ISI_PrEng (0/1)	0.177	0.195	0.049	0.361	0.718	433	
	ISI_MechEng (0/1)	0.063	0.107	0.037	1.183	0.238	433	
Country effects	UK (0/1)	0.570	0.266	0.056	−5.396	0.000	433	***
	DE (0/1)	0.051	0.294	0.053	4.612	0.000	433	***
	IT (0/1)	0.025	0.136	0.040	2.792	0.006	433	***
	ES (0/1)	0.114	0.023	0.024	−3.834	0.000	433	***
	NL (0/1)	0.152	0.133	0.043	−0.447	0.655	433	
	FR (0/1)	0.089	0.150	0.043	1.422	0.156	433	

*Significance level at 10%.
**Significance level at 5%.
***Significance level at 1%.

holds a postgraduate (PhD) degree where the mean is higher for the university-owned group.

In the invention background category, the variables that are not significantly different between the two samples are *R&D total costs* (in ln(1000€)), *Family* (a dummy for whether or not the patent is part of technologically related set of patents), *No. words in the claims* descriptions (a measure for complexity of the invention) and the *No. of IPC 4-digit* patent classes (a measure for broadness of the invention). These variables measure various aspects of the resource factors category in Markman, Gianiodis, and Phan (2008). On the basis of their reasoning, we might expect these factors to have a positive impact on firm ownership, but this is not brought out in the descriptive statistics.

Other characteristics of the invention process show more statistically significant differences. The mean number of *Man-months* invested in the invention process is higher in the case of university-owned patents (this seems to go against the prediction of Markman, Gianiodis, and Phan). The proportion of patents with *Multiple applicants* is also higher for university-owned patents, which indicates that the university often occurs as together with other (private) applicants. On the other hand, the *No. of inventors* per patent is higher for non-university-owned patents. Finally, we find that the proportion of patents resulting from cooperative research (*Cooperation*), i.e., university- and non-university-inventors involved, is higher for the non-university-owned group, as it is for patents where the respondent reported formal contractual collaboration arrangements (*FormCol*).

Finally, and related directly to our research question, for the dependent variables (commercialization and value), we found no differences between the two groups in terms of the inventor's perceived value of the patent. However, the probability of the patent being exploited was higher in the group of university-owned patents. This holds for the two specific application variables, *Licensing* (56% of university-owned patents were licensed vs. only 15% in the other group) and *Start-up* (23% of university-owned patents became the basis for new firm start-ups vs. only 8% in the other group), as well as for the summary variable *Patent used*, which includes commercial application by the patent holder.[8]

One aspect of the invention process that emerged in the literature review has not been illustrated so clearly in the descriptive statistics yet. This is the relative distribution of the importance of the research effort by the university and the firm. We can take the distribution of inventors over the two parties as an indication of this. Table 6 provides information on this variable for the sample of 384 patents for which we have this information (patents with one inventor were excluded). In this sample, slightly less than half (45%) of all patents have only university inventors, and 55% of all patents have university inventors and non-university inventors.

Within the group of patents that has non-university inventors, only 5% are *university-owned*. Within the group of patents with only university inventors, this percentage is larger (31%), although still clearly less than half. Thus, if we take the distribution of inventors over the research partners as a (broad) indication of relative marginal research impact, the data seem to support the idea in Aghion and Tirole (1994) and Conti (2008) that a higher

Table 6. Ownership and inventorship of university patents.

	Only university inventor(s)	University inventor(s) and other type inventor(s)	Total
University-owned patents	53 (31% of column)	11 (5% of column)	64
University-invented patents	119 (69% of column)	201 (95% of column)	320
Total	172 (45% of row)	212 (55% of row)	384

firm contribution to the research project increases the likelihood of firm ownership (the threshold seems to be rather low, if anything).

5. Statistical results

Taking the (lack of) differences in the variables for the rate of commercialization and value at face value, we cannot determine whether they are related to the ownership effect, or to some other underlying differences between the two samples. In other words, are the differences and similarities for commercialization and value based on university ownership, or on some other heterogeneity in the two samples? Based on the theory, the observed heterogeneity between the two samples might even be causally related to the ownership value, which would make it even more difficult to make inferences about the effects of university ownership. In order to disentangle the various effects, we proceed to the discussion of the statistical results.

5.1. Control function regressions

The results from estimating the control function regressions are summarized in Table 7. We use only patents that are owned either by a university, or by a firm. Patents with other ownership modes, such as ownership by natural persons or government research institutes, are excluded from the analysis because these types of owners do not conform very well with our theoretical distinction of either profit-motivated firms or universities as owners.[9] In all regressions, we added a time variable as control, to capture the time that had elapsed between the patent application and the survey. This allows us to control for the different lengths of time that patents have been exposed to in their diffusion process.

Table 7. Control function regression results.

	Patent used	Licensed	Start-up	Value (ln)
University-owned	0.120 (1.52)	0.371 (5.19***)	0.041 (0.94)	−0.192 (0.85)
Male				0.723 (1.79*)
Graduation	0.008 (2.17**)			
Tenure	0.006 (1.69*)	0.006 (2.67***)		
Postgraduate degree	−0.161 (1.65*)			
EPO patent appl.	0.134 (2.53**)	0.079 (2.04**)		
R&D total costs	0.042 (2.12**)			0.151 (2.59***)
Man-months		−0.024 (1.83*)	0.019 (1.77*)	
Family			0.088 (2.21**)	
No. IPC 4-digit (ln)	0.163 (2.44**)	0.092 (2.00**)		
Multiple applicants	−0.193 (1.89*)		−0.093 (1.85*)	
Cooperation (0/1)	−0.138 (2.05**)	−0.196 (3.90***)		
FormCol (0/1)			−0.119 (2.63***)	
Time				−0.135 (1.97**)
Constant				5.325 (5.81***)
Observations	366	366	281	366
(Pseudo) R^2	0.21	0.30	0.17	0.11

Notes: Country dummies and technology field dummies included in regression, but not documented. Robust *t*-test in parenthesis. The first four columns show the marginal effects of probit model evaluation at sample means. The fifth column shows OLS results. Variables *Age*, *Experience*, *No. words claim*, and *No. Inventors* were not significant in the final regressions and have therefore been excluded from the table.
*Significance level at 10%.
**Significance level at 5%.
***Significance level at 1%.

Given the different scaling of the dependent variables, we apply different regression models. In the first three columns of Table 7, which present the binary dummy variables, we applied a probit model. In the regression for value, we applied a simple ordinary least squares (OLS) model. Obviously, the nature of the estimated coefficients varies between these models.

In all cases, we started with a ‘full model’, which includes inventor background, invention background, and technology and country effects as the explanatory variables. We reduced the number of variables in this model by excluding, one-by-one, all variables that were not significant at the 10% level or higher. We only document the results of this ‘parsimonious’ model.[10] Country dummies, technology dummies and the ownership variable remained part of the regressions, independent of their significance level; the country and technology class dummies are not included in the tables.

With regard to the treatment variable (university ownership), this is significant only for the variable *Licensed*. It is not significant for the other variables, including the value measure and the summary application variable *Patent used*. Thus, our finding indicates that, overall, university-owned patents do not tend to be used more often than non-university-owned patents. Although university-owned patents are licensed-out more often, this seems to be a substitute for direct commercial application, and does not raise the overall rate of commercial application. Comparing this result with Table 5, which indicated a higher commercial use of university-owned patents, leads to the conclusion that university-owned patents are different than university-invented patents, and once we control for these differences, there is no longer a significant difference with regard to the rate of commercialization.

The results for the control variables, although not key to our research question, also provide some interesting findings. In the category inventors’ background, the variables *Graduation*, number of *EPO patent applications* and *Tenure* have positive and significant coefficients in the *Patent used* equation. The first two of these are also significant and positive in the *Licensing* equation. As these are indicators of researcher quality, this result seems to indicate that ‘better inventors produce better patents’. Having a *Postgraduate degree*, on the other hand, has a significant negative impact in the *Patent used* equation, which is counter-intuitive. Apart from the *Male* dummy, none of the variables in the inventors’ characteristics block have a robust influence on the value indicator, and no variable at all in this block enters the *Start-up* equation significantly.

Similarly, in the project characteristics block, we find economic value is explained only by R&D budget.[11] In terms of the other variables, the *No. of IPC 4-digit* categories and *Family* (both measures of complexity) are positive and significant in some of the regressions for the commercialization indicators. Thus, more complex inventions seem to be applied more often. *Cooperation*, *Multiple inventors* and *FormCol* have a negative and significant influence on the commercialization variables. This may point to problems in coordinating cooperation relations. *Man-months* has a significant and negative impact on *Licensing*, but a positive and significant impact on *Start-up*.

5.2. Treatment effects and matching

We implemented the control group (matching) approach using a two-stage process following Rosenbaum and Rubin (1983). First we estimated a (logit) regression for the treatment (ownership) variable. The predicted values of this regression provide an estimated probability that a particular patent will be university-owned. In the second stage, we constructed the control sample by drawing, for each treated patent, a control with a probability score as close as possible to the treated patent. The first stage in the treatment effect method is the estimation of the logit equation to predict university ownership. We use the same set of regressors as before.

The first stage logit-regression provides a test of the factors that were identified above to have an impact on university patent ownership. This includes the inventor-related variables that proxy for 'researcher quality' (Jensen, Thursby, and Thursby 2006). We expect that an increase in the quality of the inventor increases the probability that the patent is assigned to the university. We also look at the variables in the project characteristics block that give an indication of the complexity of the project, where we would expect that, in general, for 'more difficult' projects, the marginal university contribution to the research project increases, and hence the probability of university ownership increases (Aghion and Tirole 1994).

We apply the same process of eliminating insignificant variables from the first-stage equation. The only difference in this respect is that we accept only final specifications that satisfy the balancing restriction (this is a test of whether for a given propensity score, treated and control observations are on average observationally identical).[12] The results of these p-score regressions are presented in Table 8.

The matching approach and p-score estimation are applied to the same sample as before (only university- or firm-owned patents). Table 8 gives the estimations for the p-score (logit model). We find that inventors with a shorter time in current job (negative sign on *Tenure*), less experience in patenting (negative sign on number of *EPO patent applications* and on *Experience*) and that are older (positive sign on *Age*) tend to have a higher probability of assigning the patent to the university. This is somewhat contrary to Jensen, Thursby, and Thursby's (2006) findings that higher quality inventors are more likely to assign their

Table 8. P-score regression results, dependent variable: university ownership (logit estimation).

	Only firm- or university-owned
ES	1.071 (1.29)
DE	−3.414 (3.84***)
NL	−1.602 (2.91***)
FR	−2.137 (3.17***)
IT	−2.152 (2.24**)
ISI_ElEng	2.203 (2.45**)
ISI_Instr	1.939 (2.37**)
ISI_ChePha	2.022 (2.32**)
ISI_PrEng	2.403 (2.66***)
Age	0.108 (3.00***)
Experience	−0.146 (3.34***)
Tenure	−0.137 (3.62***)
EPO patent appl.	−1.782 (4.06***)
Man-months	0.298 (2.66***)
Family	0.714 (1.64)
No. words claim (ln)	0.53 (1.74*)
No. inventors	−0.547 (1.41)
Multiple applicants	2.7 (4.11***)
Cooperation	−2.089 (4.05***)
FormalCol	−1.701 (4.20***)
Constant	−6.029 (2.85***)
Observations	366

Notes: Robust *t*-test in parenthesis. The variable *Graduation* was not significant in the final regressions and has therefore been excluded from the table.
*Significance level at 10%.
**Significance level at 5%.
***Significance level at 1%.

patents to universities. To the extent that experience is an indicator of quality, our results at least partially contradict this expectation, suggesting that additional theoretical work on this issue for Europe would be useful.

For the project characteristics block, the presence of *Multiple applicants*, being part of a *Family*, the *Number of words in the claims* of the patent and project size (*Man-months*) increases the probability of university ownership. This seems to argue against the idea in Markman, Gioniodis, and Phan that more resources and/or more complex research projects make firm ownership more likely. The presence of non-university inventors (*Cooperation*), the *Number of inventors* in the patent or the existence of formal collaboration (*FormCol*) decreases this probability. This is consistent with the view that a higher private contribution to the research project makes private ownership more likely.

With the exception of Spain, the country dummies are negative (UK is the reference country), while the technology dummies for electrical engineering, instruments and precision engineering are positive and weakly significant (mechanical engineering is the reference technology).

The average treatments effects as measured by the control samples are presented in Tables 9 and 10. Table 9 presents the results of the Nearest Neighbour matching method; those in Tables 10 present the results of Kernel matching. The results in both tables were generated using the common support constraint. Kernel matching has the advantage that more observations are included, but standard errors for the observed treatment effect must be derived from bootstrapping. In terms of qualitative conclusions, the results for the two methods generally match (we discuss below the one exception).

Using Nearest Neighbour matching (Table 9), we observe only a significant, and positive, treatment effect for the licensing variable. The other variables are not significant, although the variable for overall commercialization (*Patent used*) is positive. Using kernel matching (Table 10), the result is similar, confirming both the positive effect on licensing,

Table 9. Nearest neighbour matching results.

				Analytical std. err.		Bootstrapped std. err.	
	Treated	Control	ATT	Std. err.	*T*	Std. err.	*t*
Patent used	79	32	0.203	0.149	1.36	0.177	1.14
Licensed	79	32	0.405	0.129	3.14***	0.153	2.65***
Start-up	79	32	0.089	0.119	0.74	0.167	0.53
Ln(Value)	79	32	0.464	0.421	1.10	0.674	0.69

Notes: ATT, average treatment effect on treated. Numbers in the first two columns and number of observations.
***Significance level at 1%.

Table 10. Kernel matching results, comparison only with firm-owned.

				Bootstrapped std. err.	
	Treated	Control	ATT	Std. err.	*T*
Patent used	79	160	0.190	0.156	1.22
Licensed	79	160	0.389	0.124	3.14***
Start-up	79	160	0.058	0.123	0.47
Ln(Value)	79	160	0.126	0.475	0.27

Notes: ATT, average treatment effect on treated. Numbers in the first two columns and number of observations. Gaussian Kernel used. Standard error by bootstrapping with 100 replications.
***Significance level at 1%.

and the absence of a significant effect on the other variables, including the overall *Patent used* variable. Overall, the results from the matching procedure are consistent with the results from the control regressions.

Thus, overall, we do not find evidence of a university ownership effect on either commercialization or the economic value of patents. Although such an effect appears to show up in the descriptive statistics (Table 5), the subsequent analysis shows that this is a result of the fact that university-owned patents are different from university-invented patents. Universities do tend to license more of their patents, but compared with firm ownership, this does not lead to a significant increase in the overall rate of commercialization. Nor do universities own more valuable patents relating from their research. Thus, we do not find any indication of market failure with regard to non-university ownership of patents resulting from university research.

6. Conclusions

The seemingly poor patenting activity of universities in Europe has been suggested as a cause of the so-called European paradox (that Europe is strong in basic science, but lags in terms of technological applications in world markets, see European Commission (2003)). As a result, it has been argued that Europe needed legislation similar to the Bayh–Dole Act in the USA, to make university patenting more attractive. An important part of these policies has been to establish the so-called TTOs at universities, and foster their role in technology-transfer at large, and university-patenting in particular. Because our data refer to a period before these policies were implemented on a large scale, we cannot address the role of TTOs directly, but our results are relevant to the literature that has analysed the role of TTOs.

We started from the empirical observation that, at least in Europe, much university research that leads to patents does not show up in the statistics because private firms rather than the universities themselves apply for patents on inventions that involve university inventors. About 80% of the EPO patents with at least one academic inventor are not owned by a university. Hence, there is no statistical record of university involvement in the patent office records, but once the data are corrected to take account of the different ownership structures in Europe and the USA, a back-of-the-envelope calculation suggests that the European academic system produces about the same share of total patenting in Europe as US universities do in the USA. Thus, the appearance of a lack of university patents in Europe is due to a lack of *university-owned* patents, not a lack of *university-invented* patents.

We then asked whether, as suggested in some of the theoretical literature, this ownership structure has a negative effect on achieving the aim of a better commercial use of knowledge produced by universities. The answer to this question is that there is not much evidence that *university-owned* patents are more used, or are more valuable from an economic point of view, than *university-invented* patents that are owned by firms.

This result raises serious questions about the effect of policies, undertaken in various EU countries, to increase the role of TTOs in managing university patents. Our research provides an assessment of the *ex ante* situation that gives rise to much less worries about a lack of university-involvement in patenting in Europe. Apparently, the market took care of university patenting, and there is no indication of market failure in this respect. This suggests that, in order to arrive at a realistic evaluation of the TTO-related policies, a counterfactual of firm-ownership of university patents must be considered explicitly, something that is not very common in the literature on TTOs. Without this, so we argue, a serious evaluation of the success of legislative changes and other policies in various European countries in terms of increasing knowledge transfer from universities to firms is not possible.

Our statistical analysis of the question whether university-owned patents are more often commercially applied, or are more valuable from an economic point of view, controlled for the different (*ex ante* observed) characteristics of university-owned and non-university-owned patents. Although we found differences in application rate (not value) before controlling for these differences, the controls rendered these differences insignificant. This implies that *university-owned* and *university-invented* patents are different, and that these differences lead to different rates of commercial application. Ownership itself does not seem to influence this. It is true that *university-owned* patents tend more often to be licensed out, but this does not lead to an overall increase in the rate of commercial use.

These results, first of all, have theoretical implications. Our literature survey shows that the main expectation is that private ownership of university patents has an adverse effect on technology transfer, in particular on the rate of commercial application and/or economic value of university research. This expectation is not born out in our statistical analysis, which implies that there is reason to revise the theoretical models in this respect. Our results seem to suggest that a European alternative to the US model of university-ownership of patents exists, and therefore it seems reasonable to suggest that the theory should take the specific European context more seriously.

The European model involves firms in university research at an early stage, (often) enabling them to own the patent to the research results. We would suggest that the observed differences between the European and US models of university patenting are a manifestation of several deeper, underlying factors. At this stage, we can only speculate about the nature of these factors, and how they are related to commercialization and the economic value of innovations. It is frequently argued (Cohen, Nelson, and Walsh 2002) that informal contacts between scientists and engineers working in the private and university sectors are the most important form of interaction, and facilitate technology transfer. It may be the case that the European model relies more on such informal interaction in the early stages of a research project (i.e., the pre-patent phase), leading to the observed tendency of firms to own patents on university research. This may increase the intensity of interaction, and thereby the efficiency, but further research would be needed to confirm this claim. Another reason could lie in the institutional differences between European and US universities, with Europe applying a model of more rigid public organization with rather rigid salary scales.

Although our conclusions rather clearly point out that some of the discussion on technology transfer and TTOs may have ignored an important issue that is very specific to the European context, it is also true that there are limitations to our study, that can only be overcome in future research. The most obvious one is that we do not have any direct data on TTOs. Focusing on later time periods may solve this problem. Another limitation is that we do not have any information on the actual process in which ownership is determined. It could well be that some of the patents that we observe as privately owned have been offered to the university, but have been refused. This would be an important factor to control for (or to use as a dependent variable in regressions similar to ours). Finally, we feel that it would be very useful to address our research questions – whether private ownership of university patents influences the rate of commercialization of university patents – in the US context. Such a comparison would certainly enrich the debate on the relative efficiency of the US and European innovation systems.

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Notes

1. The reason why our data refer to this period is that we aim to have dependable data on the economic value of the patent, which becomes obvious only after a significant amount of time has passed.
2. These results differ between countries. The shares of university patents in the samples per country are as follows (the results are presented as share in number of cases/share in weights): UK 9.01%/9.22%, DE 3.23%/3.62%, FR 4.04%/3.95, IT 4.00%/3.94%, NL 5.25%/5.18%, and ES 6.32%/6.07%. The deviation between the two percentages is most serious in Germany (DE), where we seem to have some overrepresentation of university inventions.
3. See Geuna and Nesta (2006) and references cited in their paper for preliminary evidence of this phenomenon in a few European countries.
4. The case of the UK can be explained by the fact that the only two major PROs were active in the period considered. These were DERA (now privatized as QuinetiQ) and the Medical Research Centre, both owned by the respective ministry and therefore the ownership of patents was assigned to the ministries.
5. In the period considered in our analysis, the British Technology Group (BTG) was created from the privatization of the National Research Development Corporation (merged with the National Enterprise Board), the public organization created in the late 1940s to commercialize innovations resulting from publicly funded research. Following the tradition, until the mid-1990s, BTG was chosen by a large number of universities to be the assignee of academic patents. Our sample includes 14 patents assigned to BTG, and they were classified in the companies class.
6. Although this is a subjective variable that could be severely contaminated by measurement errors, it has been extensively validated by the PatVal team and the results of this validation process seemed highly consistent (Gambardella, Harhoff, and Verspagen 2005, 2008; Giuri et al. 2007).
7. Note that the inventor that responded to the questionnaire is not always the/a university patent inventor.
8. We also tested whether university-owned and university-invented patents differ with respect to commercial use by the patent holder. Surprisingly, we found no significant difference between the two groups. Since universities are normally not in the habit of undertaking economic activity other than education and research, we expected this variable to be low for the university category. However, we found that roughly half of the university-owned patents had been used for commercial purposes by the applicant/owner. Our conclusion, based on inspection of the data, is that (university) respondents have assumed licensing to be a form of commercial application, and hence the results for this variable overlap with those for licensing.
9. Sixty-seven patents are cut from the sample as a result of this. The regressions that we ran for the samples including these 67 patents do show a weakly significant effect of ownership on *Patent used*. This seems to point out that universities are more efficient at commercializing their patents relative to individuals and/or PROs, but not relative to firms. These results are available on request.
10. The signs and significance levels of the university ownership variable are always the same for the full model and the parsimonious model, and hence our conclusions are not affected by including or excluding explanatory variables.
11. Gambardella, Harhoff, and Verspagen (2005) provide a more elaborate approach to explain patent value than we can do here, and provide more enlightening insights for the total PatVal sample.
12. If the balancing property is not satisfied, we include the last insignificant variable that we excluded, until the restriction is satisfied.

References

Aghion, P., and J. Tirole. 1994. The management of innovation. *Quarterly Journal of Economics* 109: 1185–209.

Balconi M., S. Breschi, and F. Lissoni. 2004. Networks of inventors and the role of academia: An exploration of Italian patent data. *Research Policy* 33: 127–45.

Bekkers, R.N.A., and I.M. Bodas de Araujo Freitas. 2008. Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy* 37: 1837–53.

Cesaroni, F., and A. Piccaluga. 2005. Universities and intellectual property rights in Southern European countries. *Technology Analysis and Strategic Management* 17: 497–518.

Cohen, W.M., R.R. Nelson, and J.P. Walsh. 2002. Links and impacts: The influence of public research on industrial R&D. *Management Science* 48: 1–23.

Conti, A. 2008. Development of university research with or without industry: An analysis of the factors affecting academic researchers' choice. Manuscript Ecole Polytechnique Fédérale de Lausanne, Lausanne.

Debackere, K., and R. Veugelers. 2005. The role of academic technology transfer organizations in improving industry science links. *Research Policy* 34: 321–42.

Dosi, G., P. Llerena, and M.S. Labini. 2006. The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called 'European Paradox'. *Research Policy* 35: 1450–64.

European Commission. 2003. *Third European report on science & technology indicators*. Brussels: European Commission.

Gambardella, A., D. Harhoff, and B. Verspagen. 2005. The value of patents. Paper presented at the 32nd Conference of the European Association of Research in Industrial Economics, 1–4 September, in Porto, Portugal.

Gambardella, A., D. Harhoff, and B. Verspagen. 2008. The value of European patents. *European Management Review* 5: 69–84.

Geuna, A., and L. Nesta. 2003. *University patenting in European countries: Is public research changing*? Commissioned report to the OECD. Paris: OECD.

Geuna, A., and L. Nesta. 2006. University patenting and its effects on academic research: The emerging European evidence. *Research Policy* 35: 790–807.

Giuri, P., M. Mariani, S. Brusoni, G. Crespi, D. Francoz, A. Gambardella, W. Garcia-Fontes, et al. 2007. Inventors and invention processes in Europe. Results from the PatVal-EU survey. *Research Policy* 36: 1107–27.

Heller, M. 1998. The tragedy of the anticommons. *Harvard Law Review* 111: 621–88.

Hellman, T. 2007. The role of patents for bridging the science to market gap. *Journal of Economic Behavior & Organization* 63: 624–47.

Jensen, R., J. Thursby, and M. Thursby. 2006. In or out: Faculty research and consulting. Paper presented at the Sixth Annual REER Conference, December, in Atlanta.

Lissoni, F., P. Llerena, M. McKelvey, and B. Sanditov. 2007. Academic patenting in Europe: New evidence from the KEINS database. CESPRI WP N0. 202, Universita' Commerciale Luigi Bocconi, Milan.

Macho-Stadler, I., D. Perez Castrillo, and R. Veugelers. 2007. Licensing of university inventions: The role of a technology transfer office. *International Journal of Industrial Organization* 25: 483–510.

Markman, G.D., P.T. Gianiodis, and P.H. Phan. 2008. Full-time faculty or part-time entrepreneurs. *IEEE Transactions on Engineering Management* 55: 29–36.

Meyer, M. 2003. Academic patents as an indicator of useful research? A new approach to measure academic inventiveness. *Research Evaluation* 12: 17–27.

National Science Foundation. 2004. *Science and engineering indicators*. Arlington, VA: National Science Foundation.

OECD. 2003. *Turning science into business. Patenting and licensing at public research institutions*. Paris: OECD.

Porter, M. 2001. *Innovation and competitiveness: Findings on the Netherlands*. Den Haag: Ministry of Economic Affairs, Netherlands.

Rosenbaum, P., and D. Rubin. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70: 41–55.

Siegel, D.S., R. Veugelers, and M. Wright. 2007. Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. *Oxford Review of Economic Policy* 23: 640–60.
Thursby, J., A. Fuller, and M. Thursby. 2007. US Faculty patenting: inside and outside the university. NBER Working Paper Series, no. 13256, National Bureau of Economic Research, Cambridge, MA.
Thursby, J.G., and M.C. Thursby. 2005. Faculty patent activity and assignment patterns. Report to the Kauffman Foundation, Kansas City, MO.
Verspagen, B. 2006. University research, IPRs and European innovation systems. *Journal of Economic Surveys* 20: 607–32.