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Patents owned by public research centres: EU vs. US, universities vs. public research organisations

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Abstract

Some literature has paid attention to the increase of university-owned patents in many EU countries, following the same trend in the US. We build an indicator to compare between EU and US university-owned patents in relative terms and both of them with public research organisations (PRO)-owned patents. We find that EU universities have almost caught-up US universities and EU PROs in patent ownership. We conclude that the challenge is to understand the large differences between US and EU PROs. Our econometric estimations show that while returns to scale are decreasing for university-owned patents, they are constant for PRO-owned patents, and illustrate the possibility that none of them are compatible with other alternatives for technology transfer.

Keywords: university patents, PRO patents

1. Introduction

Public research centres (PRCs) apply for patents and eventually succeed in obtaining their ownership. The trend has been increasing in the EU for the last thirty years, popularising the use of PRC-owned patents to build indicators about the technological production of academic institutions and their potential contribution to industrial application. Some reasons for the

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upsurge of PRC patents are: changes in knowledge production that have increased the capacity of PRC researchers to produce patentable inventions as well as scientific publications; changes in society demand and funding conditions that have induced an increasing number of PRCs to engage into a higher control of research results and their direct management.

Beyond these framework conditions, there has been some interest in finding the concrete inputs that explain the production of academic-owned patents, because of its importance to take decisions on the economics and the organisation of science: To what extent are PRC-owned patents a result of higher R&D? Funded by whom? If PRC-owned patents are actually a result of some of these inputs, is the trend of increasing PRC-owned patents compatible with other relevant trends in the inputs?

A good way to approach these questions with a normative dimension is the patent production function (Foltz et al, 2001; Payne and Siow, 2003; Coupé, 2003; Azagra, Fernández, Gracia, 2003; Stephan et al., 2006). The reason is that it provides quantitative evidence through econometric estimations on the relation between academic-owned patents and their determining factors. Following this approach, this paper would contribute to the debate along three main axes:

- US is said to outperform EU in the number of university-owned patents. It would be possible to test it after taking into account the influence of many differences between US and EU
- The European Research Area (ERA) viewpoint has not been tackled at the level of Member States. European evidence exists for non-econometric studies or for national or case studies. The ERA perspective requires an analysis using the Member State as a unit of observation. This could result in explaining why there are differences among Member States, even after controlling for factors like the propensity of academic inventors to appear as such in patents

not-owned by academic institutions (Meyer-Krahmer and Schmoch, 1998; Calderini et al.; 2005; Meyer, 2006; Azagra, Llerena, Carayol, 2006; Crespi et al., 2006; Lissoni et al., 2007). Are any member states more efficient than others at producing PRC-owned patents?

- Universities have received more attention than the other main scientific producers have in the public system, public research organisations (PROs). However, while some PROs have been traditionally oriented towards patenting, many others have not and thus they face similar concerns to those of universities (Azagra, Plaza, Romero, 2007). It will be possible exploring whether the behaviour of some inputs at universities and PROs is similar in terms of patenting.

Section 2 follows with a literature review to explore these issues in more detail and set testable hypothesis. Section 3 explains the data and methodology. Section 4 presents the results. Section 5 ends with some conclusions.

2. Literature review

2.1. The differences between PRC-owned patents revisited: EU vs. US

The belief that the US outperforms the EU in the number of university-owned patents is widely spread. Schmiemann and Durvy (2003) attribute it to framework conditions that make US more efficient, but which an appropriate regulation can easily overcome since EU universities have no intrinsic constraints to be as efficient in patent ownership as their US counterparts. The authors recommend thus regulatory changes leading to increased university patent ownership, that they consider a precondition for improving commercialisation and technology transfer.

The idea that there are no differences in efficiency to produce university-owned patents is arguable. Some evidence suggests that the EU presents some weaknesses in the generation of publications and citations and in the excellence of higher education institutions, as compared to the US (Dosi et al., 2006). Because university-owned patents are another result of university R&D activities, one may wonder whether they are subject to similar flaws.

Were the EU universities as efficient as the US ones in patent application or not, there is still doubts whether increasing university patent ownership is the path to follow the US model.

On the one hand, there is little quantitative evidence at country level for the EU, in relative terms to inputs. The most recent effort in this sense appears in a report by OECD (2007: pages 30-31), where the indicator used is the number of university and government owned patents over the number of total patents. This ratio shows that the US is above the EU average for both institutional sectors, although some EU member states surpass the US: Ireland, Spain, United Kingdom and Belgium in the case of universities, France and United Kingdom (again) in the case of government. This is an illustration of how expressing the number of patents in relative terms introduces complexity into the world ranking, especially because of the heterogeneity within EU member states.

On the other hand, the US may have incipiently inverted the trend and eventually reduced the number of university-owned patents, again as a percentage of total patents (Leydesdorff and Meyer, 2008).

University-owned patents as a fraction of total patents express the institutional presence of universities within a country, but a decrease in the value of this indicator it is still compatible with an increase in the efforts of universities to own more patents. We are more interested in using a measure of university R&D activities as a numerator in the ratio, as a better indicator of the propensity to own patents. We also consider that it is difficult to assess what is going on at universities without looking at the other PRCs, i.e. PROs, since they may constitute an interesting benchmark. Our point of departure is the current state-of-opinion, in order to formulate what seems an intuitive hypothesis:

Hypothesis 1. The US tends to outperform the EU in the number of PRC-owned patents even after controlling for the money PRCs spend on R&D.

2.2. Trends of university patenting and their determinants

European universities have experienced pressure to increase patent application in the last two decades or so. For this, they need to orient their inputs in the same direction. What will happen if the inputs have experienced pressures in another direction? It is difficult to consider increased university application for patents as an isolated phenomenon but rather the outcome of a collective decision making process. In this process, institutions take decisions regarding university-owned patent and their determinants at the same time, but the decisions regarding the determinants may respond to different logics, so they will not necessary align the final movement of outputs and inputs.

Which are the inputs of university-owned patents? In almost all the knowledge production functions estimated by the works mentioned in the introduction (that we will retake in section 2.4), one of the theoretical determinants of university patents are university R&D expenditures and/or other measures of university research size, like R&D staff. The impact tends to be positive and significant, with elasticities lower than one.

Within R&D expenditures, the role of private industrial funding has special importance, since firms have traditionally been more prone to engage into IPR practices and they may influence universities to adopt this practice (Henderson et al., 1998). Foltz et al. (2000) did not found any quantitative impact, though, and they concluded that industrial funding of university research would be more likely to generate privately owned patents (or what the literature would call academic invented patents, as we will discuss in section 2.3 in more detail). In support for this hypothesis, Azagra, Carayol and Llerena (2006) showed that university-owned patents were more responsive to public funding whereas so were university-invented patents to private funding. However, Azagra, Fernández and Gutiérrez (2003) detected a positive impact of industrial contract value on university-owned patents, which they attributed either to an indirect influence or to patent co-application.

Some other determinants of university-owned patent are contextual factors that we will deal with in section 2.3. For the time being, let us recall that, very often, econometric works report the impact of the theoretical inputs of the dependent variable to find the significant determinants, without having looked at the trends of those inputs. Doing so would be especially interesting in the light of the divergent trends. For instance, one may wonder whether it is coherent that the value of one input tends to decrease if it has a significant impact on university-owned patents (which are increasing). In the belief that this will not happen, we formulate:

Hypothesis 2. Determinants of university-owned patents are moving in the same direction of university-owned patents.

2.3. National legal and institutional frameworks

At country level, at least two variables may have an influence on the ownership of patents by universities: the attitude towards firms' propensity to patent and university-invented patents. Let us develop the reasons next.

Firms' propensity to patent is a priori a major force to capture national peculiarities in terms of IPR. On the one hand, it expresses the possibilities that the different legal frameworks give firms to apply for patents. Therefore, it partially controls whether universities in one country own more patents just because the legal framework allows so in general. On the other hand, in a world where firms from developed countries are eventually relying more on open source or use protection strategies alternative to patents (Arundel, 2001), it makes sense to ask whether universities are following a diverting trend.

The issue of university-invented patents is more complex. Let us start by saying that one of the first concerns about the surge of university-owned patents was the fear that it would divert universities from their traditional production of publications (Felller, 1990; Pavitt, 1998). Later quantitative evidence suggests the opposite, i.e. university publications and patents are complements, at least in terms of quantity (Carayol and Matt, 2004; Breschi et al., 2005; Azagra, Archontakis and Yegros, 2007), although some case studies suggest that the doubt still persist in terms of quality (Agrawal and Henderson, 2002).

A more recent concern is that university staff does not only appear as inventors in academic-owned patents but also in patents not applied for by universities but by other institutions, a.k.a. academic-invented patents (the terminology may be a bit confusing because, by definition, academic-owned are academic-invented patents, but the distinction has become conventional). Actually, the number of academic-invented patents may considerably exceed the number of academic-owned patents (Azagra, Carayol and Llerena, 2006). This has been an argument to support the idea that different national systems may prefer one or the other, and more concretely, that the US gives more incentives for the predominance of academic-owned patents whereas in many European countries academic-invented patents are more abundant (Crespi et al., 2006).

A question that deserves attention is analogous to the case of university publications and patents, i.e. whether academic-owned and academic-invented patents are complements or substitutes. However, the interest goes beyond the underlying assumption of allocation of scarce resources that may restrict the production of both outputs. Indeed, it may also illustrate the preference for different strategies regarding technology transfer: licensing and signalling (implicit in academic-owned patents) or joint research with industry (usually behind academic-invented patents). Here the national legal and institutional frameworks play a major role, with the design of incentives for individual researchers to gain more curricular prestige or personal income out of some options before others.

Hypothesis 3. The higher the implication in patents invented by universities, the smaller the production of patents owned by universities.

2.4. Returns to scale to university-owned patents

The extent to which an increase in scientific inputs translate into a more than, equal or less than proportional increase in scientific output has received only moderate attention in the literature about academic patenting. Thus, although it is possible to find estimations of patents as a function of R&D, there are not often mentions to the type of returns to scale. The microeconomic works on the US case using universities as a unit of observation level are a good example. For instance, Foltz et al. (2000; 2003) and Carlsson and Fridh (2002) report a positive impact a number of variables, e.g. research funding, but their econometric specifications do not allow for the interpretation of returns to scale. Payne and Siow (2003) and Stephan et al. (2007) do not address the issue either, but from the estimated coefficients, it is possible to deduce that returns may be decreasing. The only exception is Coupé (2003), who explicitly addresses the issue and finds evidence of decreasing returns to scale, although focusing on the elasticity of university R&D. The author suggests that ‘it is better to give more money to smaller universities’, to be interpreted in terms of technical efficiency.

Microeconomic studies about the European context, point into the direction of decreasing returns to scale in the production of university patents, using departments, institutes and labs within universities (Azagra, Fernández, Gutiérrez, 2003; Azagra, Carayol, Llerena, 2006). Mesoeconomic analyses for the Spanish regions, though, raise the possibility that the returns are increasing for universities –spillover effects due to the higher level of aggregation being a possible reason (Azagra, Yegros, Archontakis, 2006; Azagra, Archontakis, Yegros, 2007). However, the Spanish case may be idiosyncratic for the lower average size of their universities. To what extent the same result is applicable at the country level, for the EU, remains an open question, so we prefer to stick to the most abundant microeconomic evidence when translating it to our expectations about the results when using countries as a unit of observation.

Hypothesis 4. As apparently occurs in microeonomic studies, the returns to scale in the production of university-owned patents are also decreasing at macroeconomic level.

2.5. Universities and PROs

As mentioned in the introduction, there have been pressures to apply for patents in the whole spectrum of public research centres, but the need for a change has been more homogenous for universities, which had rarely engaged into such activity. PROs, though, may have had reactions that are more heterogeneous, because many of them had a greater industrial orientation since their creation and because the functioning of umbrella PROs is quite different from that of thematic PROs. However, the interest of estimating the determinants of PRO-owned patents is as relevant as for universities, given that PROs equally need to find legitimacy before public funding systems.

To the best of our knowledge, the only application of the knowledge production function in the context of PRO-owned patents has been the work by Azagra, Plaza, Romero (2007). The authors produced microeconomic evidence for the case of CSIC, the largest Spanish PRO. A main difference with universities was the presence of increasing returns to scale. The proposed explanation was that departments or labs at universities or universities themselves grow due to teaching duties, whereas PROs tend to augment their size because of R&D requirements than may lead to a convenient accumulation of critical mass. This justifies the next hypothesis.

Hypothesis 5. PRO-owned patents present a different behaviour than that of university-owned patents regarding the impact and coherence with the trends of their inputs and the types of returns to scale.

3. Methodology and data

We have gathered panel data on the number of PRC-owned patents and PRC R&D expenditure in millions of PPS at 1995 prices from Eurostat's online public database[1]. Since there are regular updates, it is worth noting that the data extraction dates from March 2008.

Data on patents refer to applications filed under the Patent Cooperation Treaty (PCT), at international phase, designating the European Patent Office (EPO). Years are those of the priority date, which are more meaningful from a technological or economic point of view than the application or the grant date (OECD, 2001). Although the information dates back to 1977, the period of observation starts in 1982 to match the available information for the R&D variable. The year 2004 is the last one available with information on patents. It is therefore a 23-years long period. Countries included in the sample are the 27 EU Member States and US, i.e. 28. The panel has therefore 644 observations, but 38 percent are missing for university patents and 43 percent for PRO patents. The distinction among institutional sectors such as

[1] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&scree

universities and PROs is possible after Eurostat's project on Data Production Methods for Harmonised Patent Statistics (Van Looy et al., 2006).

A limitation of using EPO patents is the possible home advantage effect that will underestimate the number of US patents (Criscuolo, 2005). Nevertheless, this effect has been studied on multinational firms and not in academic institutions.

Data on R&D expenditure refer to the extensively used measure that Eurostat compiles out of national surveys, following the Frascati Manual. In order to put it in relation to the number of patents, there is a lag of one period in order to prevent some endogeneity. This does not imply that the reader should interpret that it takes one year between spending money in R&D and applying for a patent, since the casuistic is enormous. Rather, the assumption is that one year lagged R&D expenditure is good enough as a predictor of what will happen to patents in the next period, because one-year-old R&D expenditure already incorporates information from older R&D expenditure. We mimicked the patent panel of 644 observations, 33 percent of them being missing.

A limitation of matching the patent and R&D databases is the sectoral distribution of hospitals. While patent statistics classify all hospitals into a single category, R&D statistics classify them among the rest of categories: business enterprise, government, higher education and private non-profit. Therefore, putting PRO patents in relation to PRO R&D expenditure means that we will not be including patents applied for by public, non-university, hospitals but we will be counting their R&D expenditure. The same applies to university patents and R&D from university hospitals. In order to compare between universities and PROs, this would not be a problem if the same share of hospital patents had been subtracted from university and PRO patents. One possible assumption to support that this is the case is the use of many countries: the differences in the distribution of hospitals will cancel out on average.

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n=welcomeref&open=/&product=EU_science_technology_innovation&depth=2, downloaded between March

In any case, the number of hospital patents is around 7 percent of academic patents, so the difference is not likely to be dramatic.

We start by constructing indicators of the ratio of university patents over R&D expenditure and the ratio of PRO patents over PRO R&D expenditure, and performing some descriptive analysis. Then we apply some econometric estimations of the numbers of university and PRO-owned patents, using expenditure on R&D as a determinant. To that end, we have run panel regressions testing classical regression models again fixed effects models and random effects models.

Instead of expenditure on R&D, we have also tried with R&D personnel. The two variables were highly correlated, so it was worth not including them together in the same estimation. The fit was always better for expenditure rather than personnel (a result identical to that in Azagra, Archontakis and Yegros, 2007). We have used other human capital variables, like number of researchers or ratios of R&D expenditures over R&D personnel or researchers, but they never provided additional information.

R&D expenditure is a scale variable in the sense of Furman et al. (2002), useful therefore for estimating returns to scale and test Hypothesis 4.

Other determinants of PRC patents included in the estimations are:

- The decomposition of expenditure on R&D according to its source of funding: share of business funding of R&D, share of government funding of R&D, share of other funding of R&D. In the estimations, the latter is never included, so it becomes the initial benchmark.
- Firms' propensity to patent, measured through the ratio of the number of patents owned by business firms over the business firms' expenditure on R&D
- A proxy for the appearance of PRC staff as inventors of patents not owned by PRCs -commonly known as PRC-invented patents-, calculated as:

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and May 2008.

$$\text{Space for PRC}_i\text{-invented patents} = \frac{\text{Business-owned patents}}{\text{Business-owned patents} + \text{PRC}_i\text{-owned patents}}, \quad (1)$$

i = university, PRO

The rationale behind this formula is that the more business-owned patents has an economy, in relation with the total number of patents held by both business enterprises and PRCs, the more opportunities PRC staff have to appear in patents applied for by firms.[2] This ratio would be equal to 1 if PRC staff appeared as inventors in all the space of patents and 0 if they did not appear as inventor in any patents. If Hypothesis 3 holds true, one would expect that the higher this ratio, the lower the number of patent would be, so a negative sign is expected.

Of course, this ratio is not a perfect measure, but the problem is that there are no data about the actual number of PRC invented patents for the time and geographic scope we intend to analyse. The closest attempt to generate such kind of data appears in Crespi et al. (2006) for six European countries. Their measure of university-invented patents correlates perfectly with ours and produces the same national ranking, so it gives some validity to our proxy (see Table 1). However, the correlation, although lower, it is negative and still high in the case of PROs and the national ranking is substantially different, which makes us cautious in the use of our proxy for the estimations.

{Table 1 around here}

Being PRC-owned patents in the denominator, it is also possible to argue that, our proxy necessarily correlates in a negative way to the number of PRC-owned patents. The fact that they are one-year lagged should prevent this to happen to some extent. Moreover, actual data show that it is not the case, at least for universities. The pairwise correlation with the number of patents is close to zero (and even positive). In the case of PROs, it is certainly negative and significant, which is undesirable, but at least it is small (-0.13).

The estimations shown later include final models with all variables, having checked that the results for each variable are similar to what we get when we regress them separately.

4. Results

4.1. The growth of PRCs' propensity to own patents

Table 2 shows some trends of academic patenting in the sample of EU member states compared to the US. Most trends are representative only until 2003, for the delay in granting patents that prevents from using 2004 to calculate growth rates. Notice that the number of EU member states is not constant every year, so when we refer to the EU from hereon, we will mean 'an average of EU member states'. For consistency, we replicated the descriptive analysis for each one of the six major EU member states (France, Germany, Italy, Poland, Spain and United Kingdom) and the following generalisations apply in these cases.

{Table 2 around here}

Traditionally, EU PROs have applied for more patents per unit of R&D expenditure than EU universities (column 3 vs. column 4). However, the number of EU university patents per unit of R&D expenditure has largely grown while the number of EU PRO patents per R&D expenditure has remained quite stable. If PRO propensity to patent was around ten times higher than university propensity to patent in the EU at the beginning of the period, it has decreased to less than twice higher (column 5).

The picture in US looks the reverse one: universities have more patents per unit of R&D expenditure than PROs (columns 6 and 7); the values increase much less for universities than for PROs, so the latter augment their presence in US PRC-owned patents (column 8). What is

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[2] One could argue why not including sectors of performance other than business enterprises in the space for

more, US university-owned patents per unit of R&D expenditure just begin to decline, if we focus on the late years, from 2000 onwards (column 6).

Let us notice that initially, US universities tended to apply for a larger number of patents per R&D expenditure than EU universities (column 9). The faster increase in the value of this indicator for the EU has reduced the differences with US in terms of university propensity to patent up to making them almost disappear. Regarding PROs, the stability of the propensity to patent in EU vs. the high increase of the propensity to patent in US is also making both propensities to approach, but the difference is still in favour of EU (column 10).

Hypothesis 1 finds partial support in the light of these findings. Certainly, the propensity of US universities to own patents is still higher than in EU. However, other dynamics moderate or contradict the support to Hypothesis 1: (i) EU has almost caught US up, (ii) in US the propensity is incipiently decreasing and (iii) EU PROs outperforms US ones in their propensity to patent.

4.2. Descriptive trends of theoretical determinants of PRC patents

Table 3 depicts the movement of the inputs that we are going to incorporate in the patent production function of universities and PROs. Although the calculus of growth rates is possible for 1981-2003, we have done it for 1981-2002, to keep the analysis comparable with the former section.

{Table 3 around here}

At least for the observations included in the panel, we can affirm that university R&D is increasing in real terms, as well as (remarkably) the industrial funding of this R&D. The number of university-owned patents increases faster that that of firm-owned patents, so our

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PRC-invented patents. The reason is that it is very unlikely that, e.g., if a university professor appears as inventor in a patent with a PRO or an NGO as applicants, her university does not appear as an applicant as well.

proxy for university-invented patents decreases: university staff may be eventually losing interest/opportunities to appear as inventors of firm patents.

Regarding PROs, and as opposed to universities, their R&D is decreasing in real terms, while the share of business funding is also increasing (although not so much). With the space for PRO-invented patents, the contrary of universities happens: the ratio increases.

A common determinant for both types of PRC-patents is firm propensity to own patents (column 9). It has risen twofold, i.e. much less than EU university propensity to own patents, that we saw in Table 2.

We will keep these results in mind after performing the estimations when we test Hypothesis 2, as we do next.

4.3. Econometric estimations of PRC-owned patent production functions

Table 4 presents the econometric results quantifying the relation between PRC-owned patents and their determinants.

{Table 4 around here}

For universities, the panel specification with both country and time effects produced the best model. We reduced this model, in order to gain degrees of freedom, by running an OLS regression with significant variables only, including selected time and year dummies. The share of government funding was not significant, so we dropped it. Column 1 shows the result.

The trends of the determinants of university patenting are coherent with the trends of university patenting: increased real expenditure on university R&D, share of business funding of university R&D and firm propensity to patent go along with the increasing number of university patent applications. The decreasing space left for university-invented patents is still coherent, since this variable has a negative impact on university-patent ownership. Therefore, these findings support Hypothesis 2.

The latter negative sign of the space for university-invented patents gives also some ground to support Hypothesis 3, i.e. the production of university-owned patents is excluding the production of university-invented patents. In other words, countries where universities opt for a model of technology transfer based on ownership are eventually leaving fewer possibilities to direct technology transfer.

The relation between university-owned patents and university R&D expenditure is positive and significant: the more money universities spent on R&D, the higher the number of patents they apply for. Since both variables are in logs and R&D is the only scale variable within the regressors, its elasticity determines the types of return to scale. A t-test indicates that the coefficient of the university R&D is significantly lower than one, i.e. the function presents decreasing returns to scale. This implies evidence in favour of Hypothesis 4.

In the case of PROs (column 2), a random effects model with country and not time effects is the best specification. We also reduced the initial model by selecting significant variables and it turned out that we could remove all those regarding funding structure. We examine the results vis-à-vis universities:

- Regarding the impact of the regressors, the lack of significance of the funding structure is already a difference with universities: a higher proportion of private funding is not as conducive to patent-ownership as in the previous model.
- One trend of PRO inputs is coherent with the rise of PRO-owned patents, namely the increasing propensity to patent of firms, since it has a positive impact on PRO-owned patents. Two others are not. First, the decline of PRO R&D expenditures in real terms –it is contrary to the positive effect that it causes on PRO-owned patents. Second, the increasing

ratio of business-owned patents over its sum with PRO-owned patents (our proxy for PRO-invented patents) –opposite to the negative effect on PRO-owned patents.

- In contrast with universities, PRO owned-patents present constant returns to scale –the coefficient of PRO R&D expenditures is not significantly different from one. Therefore, small PROs are as efficient as large PROs to produce owned-patents.

For PROs, lack of impact of the share of industrial funding, less coherence between inputs and outputs and different types of returns to scale mark the difference with universities and constitute therefore evidence to support Hypothesis 5.

5. Conclusions

PRC-owned patents are the result of, among other things, PRC expenditure on R&D. In this paper, we have shown that the quantification of the relation between these two variables using countries as a unit of observation is useful to adopt a European Union perspective in two senses: it allows reinterpreting the US model (the traditional benchmark) and understanding the returns to scale for EU Member States. This work has also proved that extending the analysis of university owned-patents to the case of PROs and study both simultaneously provides relevant insights into the economics of science.

It is true that the US outperforms the EU in university-owned patents even when measured through the propensity to patent out of a unit spent in R&D. However, EU countries have almost caught-up with US, so additional efforts should be further justified, in the light of possible disadvantages (Geuna and Nesta, 2006). What is more, EU countries outperform US in the propensity of their PROs to hold patents. This suggests that the EU never lagged behind the US, but simply organised its public research system to put the accent on technology ownership on PROs rather than universities. The increasing incentives for universities to apply for patents in the EU in the last two decades may have ignored that this equilibrium could be adequate and pursued an alternative model for the sake of sheer imitation. Even so, if the fear is that US outperforms EU, EU should take into account that the propensity to patent of its PROs is stagnating, while in the US it is increasing.

While some studies attribute the incipient decline of US university-owned patents to their lack of a clearly positive impact –a feature that also applies to EU university-owned patents–, this paper suggests that decreasing returns to scale at national level may be at stake. That is to say, smaller countries, in terms university R&D spending –or read smaller Member States in the context of the ERA–, are more efficient in the production of EU university-owned patents. It is still a political choice to favour them, given this higher efficiency, or larger countries, that do not have to go yet such a long way through. What counts is that R&D policymakers should be aware that indiscriminate funding would lead to uneven results. Alternatively, they could look at the PRO-model. According to our findings, constant returns to scale at national level prevail in the case of PRO-owned patents. For PROs, smaller countries are as efficient as larger countries. This difference may be due to the teaching mission of universities, which does not exist in the case of PROs. R&D at universities diverts into scientific outcomes, like patents, and teaching, whereas at PROs it focuses on the former. If desirable, increasing synergies between university scientific products and research could be a way to make universities more similar to PROs in terms of patent-ownership.

Our research also illustrates, in a tentative way, the idea that public technology ownership, in theory obeying to the purpose of technology transfer, may not be compatible with direct technology transfer. In other words, countries with more PRC-owned patents seem to leave less space to PRC-invented patents. Our measurement to support this finding was very imprecise, but if future studies confirm it, it would make a plea for strengthening the coherence between different alternatives of knowledge transmission between PRCs and the economy.

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Table 1
Two measures of PRC-invented patents in six European countries

Country	Share of university-invented patents over all university patents (Crespi et al, 2006)	Space for university-invented patents	Share of PRO-invented patents over all PRO patents (Crespi et al, 2006)	Space for PRO-invented patents
France	88.33%	99.29%	68.83%	89.29%
Germany	96.30%	99.76%	27.42%	99.88%
Italy	96.00%	99.52%	69.23%	98.45%
Netherlands	79.66%	98.85%	42.50%	99.53%
Spain	47.06%	97.12%	42.86%	98.23%
UK	67.63%	97.30%	100.00%	94.16%
Correlation with previous column		0.95		-0.62

Table 2
PRC patents per year

1 Priority year of patent application (t)	2 Number of EU Member States with available information	3 Number of EU university patents (t) per university R&D expenditure (t-1) in million of PPS at 1995 prices	4 Number of EU PRO patents (t) per PRO R&D expenditure (t-1) in million of PPS at 1995 prices	5 Ratio (4)/(3)	6 Number of US university patents (t) per university R&D expenditure (t-1) in million of PPS at 1995 prices	7 Number of US PRO patents (t) per PRO R&D expenditure (t-1) in million of PPS at 1995 prices	8 Ratio (7)/(6)	9 US vs. EU universities (6)/(3)	10 US vs. EU PROs (7)/(4)
1982	7	0.02	0.22	8.98	0.11	0.03	0.29	4.34	0.14
1983	4	0.02	0.28	17.46	0.08	0.03	0.40	5.08	0.12
1984	6	0.03	0.27	9.61	0.10	0.03	0.32	3.79	0.13
1985	4	0.03	0.31	9.97	0.15	0.04	0.24	4.76	0.12
1986	6	0.04	0.33	7.90	0.13	0.03	0.26	3.08	0.10
1987	6	0.04	0.38	10.65	0.14	0.04	0.32	3.79	0.11
1988	7	0.05	0.35	7.58	0.14	0.05	0.37	3.10	0.15
1989	8	0.05	0.36	7.69	0.16	0.05	0.34	3.41	0.15
1990	9	0.04	0.28	8.04	0.17	0.06	0.36	4.80	0.22
1991	7	0.04	0.27	7.51	0.16	0.07	0.42	4.56	0.26
1992	13	0.04	0.19	4.54	0.18	0.08	0.48	4.20	0.45
1993	9	0.04	0.21	4.70	0.20	0.07	0.35	4.61	0.35
1994	13	0.05	0.22	4.65	0.20	0.07	0.35	4.13	0.31
1995	8	0.06	0.22	3.62	0.27	0.07	0.27	4.50	0.33
1996	17	0.07	0.21	3.05	0.30	0.09	0.30	4.31	0.43
1997	14	0.09	0.23	2.50	0.31	0.09	0.30	3.40	0.41
1998	17	0.11	0.22	2.01	0.34	0.10	0.31	3.08	0.47
1999	17	0.14	0.22	1.62	0.31	0.10	0.33	2.28	0.47
2000	19	0.14	0.23	1.62	0.31	0.10	0.34	2.18	0.45
2001	18	0.16	0.22	1.39	0.25	0.10	0.39	1.62	0.46
2002	22	0.15	0.21	1.42	0.25	0.09	0.38	1.63	0.44
2003	17	0.17	0.23	1.37	0.21	0.09	0.42	1.27	0.39
2004	19	0.09	0.14	1.54	0.10	0.05	0.52	1.13	0.38
Growth rate 1982-2003		575%	3%		98%	181%			

Table 3
Trends of theoretical determinants of PRC patents

1 Year	2 Number of EU Member States with available information	3 University R&D expenditure in millions of PPS	4 Share of business funding of university R&D expenditure	5 Space for university-invented patents	6 PRO R&D expenditure in millions of PPS	7 Share of business funding of PRO R&D expenditure	8 Space for PRO-invented patents	9 Number of firm patents per firm R&D expenditure in million of PPS at 1995 prices
1981	7	2,092	1.99%	97.88%	2,771	3.94%	96.99%	0.91
1982	4	2,848	1.93%	99.40%	4,913	2.15%	95.81%	1.36
1983	6	2,593	3.40%	99.15%	3,725	3.80%	95.81%	1.17
1984	4	3,169	3.53%	98.86%	4,742	4.81%	95.43%	1.34
1985	6	2,948	4.28%	99.19%	4,136	6.15%	96.27%	1.27
1986	6	3,067	3.79%	99.06%	4,631	5.75%	95.86%	1.27
1987	7	2,921	4.13%	98.91%	3,692	4.26%	97.03%	1.39
1988	8	2,756	4.97%	97.93%	3,775	4.67%	96.80%	1.30
1989	9	2,804	5.91%	99.01%	2,944	4.96%	97.31%	1.33
1990	7	3,412	5.41%	98.79%	3,897	5.89%	96.24%	1.29
1991	13	2,618	6.45%	98.40%	2,874	6.91%	97.41%	1.57
1992	9	3,580	5.20%	97.32%	3,926	7.16%	96.15%	1.54
1993	13	2,834	5.73%	98.85%	3,034	7.28%	97.53%	1.89
1994	8	4,212	6.50%	97.81%	3,827	9.46%	93.37%	1.92
1995	17	2,327	5.38%	97.12%	2,842	7.60%	97.56%	1.65
1996	14	2,754	5.22%	96.53%	2,997	9.41%	97.37%	1.74
1997	17	2,319	5.62%	97.05%	2,414	7.50%	98.36%	1.80
1998	17	2,327	6.63%	96.32%	2,793	8.24%	98.76%	2.15
1999	19	2,268	7.14%	94.84%	2,513	8.60%	96.87%	1.87
2000	18	2,451	7.19%	94.92%	2,679	7.89%	98.76%	2.36
2001	22	2,244	6.59%	94.55%	2,377	8.93%	98.16%	1.61
2002	17	2,999	7.63%	95.51%	2,469	8.72%	98.66%	1.79
2003	19	2,856	8.26%	94.27%	2,666	6.18%	98.86%	1.15
Growth rate 1981-2002		43%	283%	-2%	-11%	121%	2%	97%

Table 4
Determinants of PRC-owned patents

Model	1 Ordinary least squares regression	2 Random Effects Model
Dependent variable	Ln number of university-owned patents	Ln number of PRO-owned patents
Number of observations	290	277
R^2	.95	.95
Adjusted R^2	.95	.95
Variable	Coefficient (t-ratio)	Coefficient (t-ratio)
Constant	16.07 (13.19)	11.01 (6.35)
Ln {PRC} R&D expenditure in millions of PPS	.30 (3.49)	1.05 (9.45)
Share of business funding of {PRC} R&D expenditure	4.88 (3.63)	
Space for {PRC}-invented patents	-15.24 (-13.01)	-15.37 (-9.91)
Ln firm propensity to patent	.88 (11.10)	.83 (8.13)
Country effects	Yes (selected)	Yes
Year effects	Yes (selected)	Not significant

For independent variables, {PRC} is university in model 1 and PRO in model 2. R^2 is that of the related fixed effects model in model 2.