What Determines University Patent Commercialization?
Empirical Evidence on the Role of IPR Ownership

Abstract

This article addresses the commercialization of academic patents, developed in both universities and public research organizations (PROs). We distinguish between university-owned and university-invented patents to analyze if and how patent ownership affects the probability of commercialization and, similarly, if the characteristics of national university intellectual property right (IPR) regimes correlate with it. We study three commercialization channels—sales, licensing, and spin-off formation—appear in a sample of 858 university and PRO patents filed with the European Patent Office between 2003–2005 across 22 countries. To analyze differences in commercialization outcomes, this study employs a multivariate probit model. The results suggest that PRO ownership is negatively associated with the likelihood of selling the patent and creating an academic spin-off; university ownership positively affects the patent's licensing uses. Finally, the institutional IPR regime has a negative effect on the probability of selling a patent.

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1. Introduction

In the past 30 years, attention to the transfer of knowledge developed within universities to industry settings has increased dramatically. In addition, this transfer has come to be considered a natural stage in the evolution of the modern university, for which contributions to economic development represent a central goal, beyond more traditional mandates of education and research (Rothaermel et al., 2007). Thus researchers investigate commercial exploitations of university patents, such as through licensing agreements (Shane, 2002; Thursby and Thursby, 2002; Sine *et al*., 2003) or the formation of spin-offs (Shane and Stuart, 2002; Wright et al. 2006; Munari and Toschi, 2011).

A critical issue in this research field is the ultimate ownership of universities' intellectual property rights (IPRs), as differentiated by university-owned versus university-invented patents (Geuna and Nesta 2006; Lissoni, 2012). In the former case, patented inventions generated by publicly funded research are owned by the university that employs the academic inventor. In the latter case, ownership of patents generated by academic inventors remains with these inventors, or a corporation or organization with which they associate, not the university itself. This debate arose largely from the passage of the U.S. Bayh-Dole Act 30 years ago, which allowed universities to own patents arising from federal research grants. Subsequently, similar legislative reforms implemented around the world (especially in European countries) aimed to strengthen institutional patent ownership rights and encourage transfers of university research to industry settings (Geuna and Rossi, 2011; Grimaldi *et al.,* 2011). Extant literature analyzes legislative changes governing university IPR ownership in different countries (Mowery and Ziedonis, 2002), the distribution of academic scientists' patenting activity in various countries (Baldini *et al*., 2006; Lissoni *et al*., 2007), and factors that might explain the assignment of academic patents to universities rather than corporations or other applicants (Markman *et al.,* 2008; Thursby *et al.,* 2009).

Yet empirical evidence about the consequences of university IPR ownership patterns for the success of technology transfer activities remains limited, in particular with regard to the commercial uses of academic patents. Existing studies rely on analyses conducted at the university level, rather than addressing single inventions (Bercovitz et al., 2001; Thursby and Thursby, 2002; Kenney and Patton, 2011), or focus on the experiences of single, often successful universities (Shane, 2002). A few recent empirical studies compare university-owned with university-invented patents in terms of their underlying quality (Czarnitzki *et al*., 2011) and their commercial exploitation outcomes through licensing or spin-off creation (Crespi *et al*., 2010). Such limited attention is surprising though, in that the ultimate aim of legislative reforms was to foster the transfer of knowledge and technology from academia to industry and enhance the exploitation potential of universities' research outcomes.

To extend this initial stream of literature, we offer three important contributions. First, we investigate whether ownership of a patent by a university or public research organization (PRO) affects the ultimate likelihood of commercialization, in the form of a sale, licensing, or spin-off formation. By including the sale of patents, in addition to licensing and new venture formation, we acknowledge recent contributions that emphasize such sales as an important, under-investigated exploitation route (Serrano, 2008). Second, we compare the commercialization outcomes of university/PRO-owned and -invented patents by exploiting an extensive data set that spans multiple countries, such that we offer a comparatively broad geographic scope in our analysis. Third, with our multicountry sample, we compare commercialization outcomes for university/PRO patents in countries characterized by different IPR legislative systems, such as institutional ownership regimes that grant the university ownership rights over the results of publicly funded research generated by researchers, versus systems that prioritize professors' privileges to own the results of publicly funded research they conduct.

Our sample of 858 university and PRO patents, filed with the European Patent Office (EPO) with priority dates from 2003–2005, spans 22 countries and includes data collected through PatVal II studies in Europe, the United States, and Japan. From these extensive data, we determine that the ownership patterns of university/PRO patents have significant impacts on the likelihood of commercialization, in terms of licensing or sale. University-owned patents achieve a higher likelihood of being licensed, while PRO-owned patents are less likely to be sold to a third party or used to found a new firm, compared with university/PRO-invented patents. We find no significant effects of ownership patterns on the probability of creating spin-offs to exploit the patent. Licensing is more common in countries characterized by an institutional ownership regime, whereas patent sales are less frequent in such settings. To arrive at these results, we introduce our theoretical background next, then present the empirical approach that leads into our discussion of the results.

2. Background

2.1. Institutional reforms on University IPRs

Economic literature has devoted substantial attention to understanding and empirically assessing whether academic research ultimately leads to concrete commercialization in the form of industrial applications (Henderson et al., 1998; Etzkowitz *et al.,* 2000; Hall *et al.,* 2001; Mowery and Ziedonis, 2002). Much of this research considers the role that universities serve in knowledge and technology transfer processes, including licensing agreements (Thursby and Thursby, 2002; Sine *et al.,* 2003), academic start-ups, spin-offs (Shane and Stuart, 2002; Wright et al., 2006; Aldridge and Audretsch, 2011), or university–industry research collaborations (Geuna, 1998; Hall et al., 2003; Oliver, 2004; Link and Scott, 2005). Interest in this topic largely initiated with the establishment of the U.S. Bayh-Dole Act, legislation passed in 1980 to address the intellectual property of federally funded research. This legal initiative set new rules for universities in their interactions with funding agencies that sought to reinforce their IPR regimes. In particular, the Act helped reduce uncertainty about the commercialization of federally funded research, leading to a significant increase in the number of academic patents (Henderson *et al.,* 1998). Although some contributions indicate that the Bayh-Dole Act helped change university commercialization (Henderson *et al.,* 1998; Siegel *et al.,* 2007), critical views question the effectiveness and social impact of such institutional arrangements (Kenney and Patton, 2011; Litan *et al*., 2007).

In the wake of this U.S. experience, a series of structural changes to university IPR legislations was introduced in Europe starting in the late 1990s, with the objective of stimulating more effective commercialization of academic research. Most European countries, with the exceptions of Sweden and Italy, moved away from their previous system, based on inventor ownership (professor's privilege), and adopted a new system centered on institutional ownership, in which the university employing the inventor retained the ownership rights on patents generated by publicly funded research (for a detailed review, see Geuna and Rossi, 2011). In contrast, Sweden did not abolish professors' privilege, and Italy moved away from institutional IPR ownership and toward inventor ownership, in a reverse of the general trend. In addition, huge heterogeneity has persisted in the ownership patterns of university inventions, both across and within countries, due to differences in the national laws and specific university bylaws (Geuna and Rossi, 2011). The shift in IPR ownership was has been accompanied generally by the creation, institutionalization, and reinforcement of specialized structures (e.g., incubators) and the emergence of dedicated policies and funding sources that aim to strengthen industry–university relationships (Baldini, 2009; Jacob *et al.*, 2003).

2.2. Exploitation of academic patents: the impact of university ownership

The underlying assumption these legislative IPR reforms is that the IPRs ownership on the results of academic research activities rests a central element to foster the transfer of knowledge between academia and industry, though IPRs represent only one type of transfer mechanism (Fini et al., 2010). Legislative reforms in support of institutional ownership of academic patents sought to provide adequate incentives for universities and PROs to develop technology transfer capabilities and invest in patenting and commercialization structures, because they enjoyed greater ownership certainty (Geuna and Rossi, 2011). Institutional ownership allows universities and PROs to create technology transfer offices (TTOs) that centralize, professionally manage, and strengthen technology transfer procedures. This step appeared necessary to foster technology transfer activities, in that professors and researchers often lack the expertise, business knowledge, commercial relationships, financial resources, or interest to engage in commercialization. Nevertheless, the institutional ownership model suffers from potential inefficiencies, such as the risk of ineffective incentives, the introduction of additional layers of complexity and bureaucratization in the technology transfer process, and the potential to distort pure research activities if researchers begin to pursue objectives linked to economic exploitation (Kenney and Patton, 2011).

Limited empirical research has compared institutional ownership regimes with alternatives, such as an inventor ownership regime, in terms of their effectiveness for commercialization. Instead, existing research focuses mainly on the factors that determine final ownership of an academic patent and offers two main insights. First, studies of the impact of legislative reforms on overall academic patenting trends in various countries help define the share of university-owned patents, compared with university-invented ones (e.g., Della Malva *et al*., 2008; Meyer and Tang, 2007; von Ledebur, 2009). Second, other studies assess empirically the factors that influence the ownership patterns of academic patents (Lissoni, 2012; Markman et al., 2008; Thursby et al., 2009) and identify series of determinants that typically influence ownership decisions, such as institutional, organizational, agency, resource, and entrepreneurial factors.

Beyond these clarifications about what determines ownership, limited empirical evidence reveals whether and how a successful technology transfer from academia to industry might depend on ownership patterns. Recent studies (e.g., Crespi *et al*., 2010) highlight that the value of academic and corporate patents might not differ in the long-term (Czarnitzki *et al.,* 2011), especially if inventors have accumulated patenting experience and the TTOs are well structured (Sterzi 2011). Only limited studies, to the best of our knowledge, compare the actual commercialization outcomes of university-owned and university-invented patents. Kenney and Patton (2011) compare the number and type of spin-offs generated by six universities and find that inventor ownership might have a positive effect on entrepreneurship. Crespi *et al.* (2010) address single inventions, using a multicountry data set based on European survey data. Their comparison of the commercial exploitation of university-invented patents relative to university-owned patents does not support the existence of significant differences in commercialization outcomes between the two categories, though the likelihood of licensing seems significantly higher in the case of university-owned patents. Thus existing literature provides only limited, ambiguous findings related to the impact of university ownership of academic patents on their ultimate commercialization.

To address this gap, we seek to understand if ownership of university and PRO patents influences their ultimate exploitation by comparing university/PRO-owned and university/PRO-invented patents, across countries characterized by either an institutional or an inventor ownership regime. We consider three exploitation channels: sale, licensing, and academic spin-offs. Thus we recognize that the sale of a patent is an important avenue for commercialization; ignoring it may provide only a partial picture of technology transfer activities by universities and PROs (Serrano, 2008). Furthermore, we assess whether the different university IPR regimes adopted at the national level influence the final exploitation of academic patents. With this multicountry comparison, we can compare the actual exploitation rates of university and PRO patents in countries that adopt institutional versus inventor ownership arrangements and shed new light on the ultimate effects of related legislative reforms.

3. Empirical Analysis

3.1 Data and Sample

The unit of analysis of this study is the patented invention. To explain the probability of a given university and PRO patent to find a commercial exploitation in terms of licensing, sales, and new venture creation, we employ a unique and extensive dataset drawn from the PatVal II survey, carried out between 2010-2011 across 20 European countries (Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Sweden, and Slovenia), plus Israel, USA, and Japan. The survey includes information on individual inventors and the invention process of 22,533 EPO patents with priority dates 2003-2005, corresponding to a response rate of 20%[1]. It covers all technological fields and includes small, medium, and large organizations including private firms, universities, and public research organizations (PROs). For the purposes of this paper, we focus on patents of inventors employed at universities or PROs at the time of the patent application, according to the information provided by the inventor in the survey (1324 observations). By excluding observations with missing information on the variables used in our analyses, we end up with a final sample of 858 university and PROs patents.

[1] The PatVal II survey was developed within the EU funded InnoS&T project "Innovative S&T indicators combining patent data and surveys: Empirical models and policy analyses". For further details about the survey methodology, sample and descriptive statistics see the final report Final Report (2011) available at http://cordis.europa.eu/fetch?CALLER=DOCS_PUBL&ACTION=D&LAN=EN&RCN=13262

3.2 Dependent Variables and estimation model

In our regressions, we estimate the likelihood of three forms of commercialization of university and PRO patents: *patent licensing, patent sale* and *spin-off formation*. The Patval-II surveys asked inventors information about the commercial use of the patent at the time of the survey. Drawing on the responses of the inventors in the survey, we build the following variables:

- *Patent licensing* is a dichotomous variable equal to 1 if the patent has been licensed by the patent holders to an independent party at the time of the survey, and 0 if not. A detailed description of our variables and the descriptive statistics appear in Tables S1 and S2 of the "Supplementary Material".
- *Patent sale* is a dichotomous variable equal to 1 if the patent has been sold by the patent holders to a third-party at the time of the survey, and 0 if not.
- *Spin-off formation* is a dichotomous variable equal to 1 if the patent has been exploited to create a new firm at the time of the survey, and 0 if not.

In our sample, 10.3% of patents have a multiple use[2]. We take into account the fact that alternatives are not independent by using a multivariable probit model in our estimations.

With this model, we test simultaneously the probability that a patent would be commercialized through a sale, licensing, or a spin-off (Cappellari and Jenkis, 2003). A detailed explanation of the choice and the characteristics of the methods appears in Section S3 of the Supplementary Materials.

3.3 Explanatory Variables

The two main explanatory variables in our estimations are the ownership of the patent and the type of IPR legislative regime concerning university patents adopted at the country level.

[2] Precisely, 2.4 % of patents are both sold and licensed, 2.1% are sold and used to found a spin-off, 4% are licensed and used to create a spin-off and 1.7% are recorded with all three uses.

Concerning patent ownership, we construct four dummy variables (*University-owned*, *University-invented*, *PRO-owned*, *PRO-invented*) indicating if the university or the PRO is the owner of the patent of an inventor employed at the university or at a PRO, or if the university or PROs are not owner of such patents invented by their employees. By using these four variables, we can distinguish the institutional context where the patent has been invented (University or PRO) from the ownership of the patent.

Institutional ownership regime is a dummy variable equal to 1 if the inventor's country adopted the institutional ownership regime of university patents, and 0 otherwise (for countries characterized by the professor's privilege regime). We used the classification proposed by Geuna and Rossi (2011) in order to differentiate countries with institutional ownerships regime from those with professor's privilege regime in the period 2003-2005, corresponding to the priority dates of the patents included in our sample. Accordingly, in that period the professors' privilege regime was in charge in the following countries: Finland, Italy, Hungary, Slovenia, Sweden. In all the remaining countries included in our sample, the institutional ownership regime was in charge.

In order to identify country-specific effects beyond the institutional regime, in alternatively estimations we include dummy variables for each country as a substitute of the dummy *Institutional ownership regime*. However, since in some countries the number of observations is small, we created two dummy variables grouping small countries respectively adopting an institutional or a professor's privilege regime (*Small countries (instit. regime)* and *Small countries (prof. privilege)*).

3.4. Control variables

By including a series of control variables in our estimations, we were able to reduce unobserved heterogeneity that might affect the probability of commercial exploitation. Therefore, at the inventor level, we controlled for the age of the inventor at the time of the invention and the length of her or his research experience. We also included an indicator of the number of published articles related to the invention, to measure the relation between the invention and scientific research results.

At the invention process level, we included indicators of the financial resources used to develop the patented invention (Markman et al., 2008) and the type of benefits offered to the inventor to develop and commercialize the invention. Finally, we included dummies for the five major technological fields. In additional estimations carried out as robustness checks (reported in the supplementary material) we include dummies indicating if there were co-applicant or co-inventors in other organizations, and a control for the value of the patent. We also control for the patent stock of the patent applicant, as a measure of its patent intensity.

Table S4 illustrates the pairwise correlations of these variables (see the "Supplementary Material").

4. Results

4.1. Descriptive statistics

We present the descriptive statistics related to the commercialization of academic patents to highlight the existence of potential differences across patent sales, licensing, and spin-off creations, which might depend on ownership patterns and institutional IPR regimes. In Table 1, we compare our PatVal II data with Crespi et al.'s (2010) sample of European university and PRO patents with priority dates 1993–1997, which they drew from the first PatVal survey. The comparison suggests increasing trends in Europe in the share of both university- and PRO-owned patents relative to university- and PRO-invented patents. In our sample, the share of university-owned patents is 54% of the total (55% if we only consider the six countries in Crespi et al.'s study), whereas Crespi et al. find a value of only 18%. Furthermore, PRO-owned patents represent 79% of all PRO patents in our sample (81% in the six countries of Crespi et al.'study) but 42% in Crespi et al.'s study. These data suggest that reforms like the Bayh-Dole Act, implemented over a decade in multiple countries, effectively shifted the balance of patent ownership toward universities and PROs.

Table 1

Another important empirical finding reveals that most university and PRO patents remain non-commercialized[3] (Table 2). Approximately 69% of university and PRO patents have not been commercially exploited; no significant differences seem to emerge in this respect between PRO-owned versus -invented patents, while university-owned patents are more commercialized than university-invented patents. If we consider the different commercialization channels in more detail, we also derive some interesting insights regarding the effects of patent ownership. In the subsample of university patents, the highest percentage of university-owned patents gets exploited through licensing (34%), whereas a lower average percentage of PRO-owned patents is exploited by licenses (about 15%). Still, licensing is the most frequent channel of exploitation for PRO-owned patents. In contrast, PRO-invented patents generally are more exploited through new ventures or sales.

In Table 3 we detail the distribution of our sample according to national IPRs regimes. We show that the rate of academic patent commercialization is nearly the same between the two types of national IPR regimes. In countries with institutional IPRs, licensing is the most common commercialization form: 25.67% of university and PRO patents are licensed. Among countries that prioritize professors' privileges, 17.14% of patents are used to found a new venture, a percentage that is not notably different from that in countries that adopt an institutional ownership regime. The most evident difference emerges for patent sales: Only

[3] As illustrated in Table S1, we define a patent as commercialized if it has been licensed, sold, or used to create a spin-off. The sum of the shares of three commercialization forms in Table 1 does not correspond to the share of commercialized patents because, as explained in Section 3.2, patents may have been commercialized in multiple forms.

7.96% of patents were sold in countries that adopted an institutional ownership regime, while about 16% of them get sold when the nation adopts professors' privileges.

Table 2 - 3

4.2. Multivariate analysis

Table 4 contains the results of the multivariate probit estimations.

The first specification (model 1) assesses the effect of patent ownership of universities and PROs and of the national university IPR ownership regime on the likelihood of commercializing patents. Compared to the baseline case of university-invented patents, our results indicate that ownership by PROs typically has a negative influence on the probability of a sale (also if compared to PRO-invented patents), whereas ownership by universities correlates positively and significantly with the probability of licensing. We also observe that PRO-owned patents are less likely to be exploited through academic spin-off formation.

The institutional ownership regime has only a significant, negative effect on the probability of selling a patent .

Model (2) replaces the IPR ownership regime of the country with a dummy for the country itself, to test if a country-specific effect exists. In particular, we note that the United States has an efficient technology transfer system, and its rate of licensing and spin-off creation are significantly higher and more positive relative to other countries, largely due to the longer duration of its policies in support of technology transfer (1980 Bayh-Dole Act). Also UK patents are more likely to spawn a new firm. We also find that patents in Japan are less likely to be sold as well as patents from smaller countries with an institutional ownership regime.

It is worth noting that also controlling for country effects, the other results remained consistent. The only difference is that the effect of PRO-owned patents on the probability of creating a spin-off remains negative but becomes non significant.

Table 4

The signs of several control variables are statistically significant with regard to each commercialization channel. The number of published articles related to the invention significantly increases the probability of licensing and creating a spin-off. That is, an invention that appears relevant, according to related academic publications, can be retained by the universities and licensed or spun off, because it tends to attract market attention. The experience of the inventor affects licensing and spin-off formation negatively, suggesting that such inventors are more oriented toward scientific research than commercialization-related activities. Financing mechanisms do not significantly influence the commercialization process, except when resources come from other organizations or customers, which positively affect the probability of selling the patent. Not surprisingly, an incentive system based on salary increases is positive and statistically significant for any form of patent commercialization. In unreported estimations we exclude this potentially endogenous variable and results remain similar, with the exception of the dummy for university-owned patents that positively and significantly (at 10% level) affects the probability of spin-off formation.

4.3. Robustness checks

We conducted several additional checks to validate our results.

In alternative to the four dummy variables indicating patents owned or invented by university and PROs, model (3) includes a dummy for *University* (baseline: PRO) and an aggregate dummy for University and PRO ownership (Table S5). Consistently with our descriptive statistics, results highlights that universities are more likely to commercialize patents in any form, while the effect of ownership remains significant on the probability of licensing. The negative effect of PRO-ownership on the probability of sale and spin-off instead disappears in this aggregate form. All other results remain similar.

Table S6 shows the results of estimations of model (1) with additional controls. Precisely, model (4) controls for the possibility of co-ownership of the patent by including dummies for the presence of a coapplicant, or of an external inventor working in a different organization. Model (5) adds the patent stock of the applicant organization in order to rule out that our results might be biased by the patent intensity of the employer.

Model (6) finally includes two potentially endogenous variables: perceived patent quality and financing resources from venture capitalists. As expected, low-value patents are negatively associated to licensing and spin-offs. In terms of financing resources, VCs funds relate positively to spin-off formation and sale. Venture capitalists often have a mission to finance academic spin-offs and accelerate the technology transfer process, so it is likely that an inventive process supported by this financial source will end up as a new venture. In addition, VCs might finance a short-term project to create profits, which would explain why VC-related financing resources are associated with patent sales. All these additional checks finally produced results consistent with our initial findings.

A potential measurement problem in our estimations with respect to patent sales, since the Patval survey does not specify the specific type of change in the ownership associated to patent sale. In order to address this issue, we collected further data from a secondary source – the EPO Register - in order to double check those observations related to patent sale in our dataset. We identified three different types of transactions related to such observations: i) a change of applicant (48 cases); ii) a change in the representative (24 cases), indicating a change of professional and authorized representative allowed to represent the applicant at the

EPO; iii) an application withdrawn (5 cases). As a robustness check, in unreported estimations we replicated our multivariate probit estimations by adopting more restricted definitions of patent sale: excluding only the cases of representative change, excluding only the cases of application withdrawn, and excluding both representative change and application withdrawn (i.e. the sample includes therefore only effective sales as change of applicant). Results, available from the authors, remain largely unchanged.

Further checks not discussed in the paper are reported in Section S8.

5. Discussion and conclusions

Our results show that university and PRO ownership of patents has a significant role for their commercialization, but this effect changes with the type of exploitation route and the organizational context (PRO vs university). PRO-ownership affects patent sales and spin-off creation negatively while university-ownership enhances licensing. Licensing requires a long-run investment from both the inventor and the organization, as well as significant ex post monitoring and control investments. Therefore, this type of exploitation is favored mainly when the university holds a stake in the patent, such that it can provide stronger support both ex ante and ex post during the commercial exploitation process. Selling patents instead is a more direct, probably easier mechanism to exploit the patents for the inventor, providing immediate benefits to the owner. As in the case of licensing, selling involves ex ante search, valuation, and negotiation costs, but it does not induce any significant ex post costs, in that it is a one-shot ownership transfer. This reasoning might explain why PRO-invented patents tend to be sold more frequently than PRO-owned patents. The finding that patent ownership does not have a significant impact on spin-off formation suggests indirectly that ownership of IPRs by academic inventors might facilitate spin-offs, without incurring significant negotiation costs with the university. This evidence is in line with arguments advanced by

Kenney and Patton (2011), who suggest that different models encourage different commercialization solutions, such that institutional ownership relates to licensing, while inventor ownership is more identified with spin-off creation.

Our results also indicate that PRO patents seem to have significantly lower commercialization rates than university patents, especially when the PRO is the owner of the patent. This outcome might reflect various factors, including IPRs internal policies and capabilities. We thus note some critical factors associated with the commercialization of academic patents, such as the scientific roots of the inventions, the presence of an incentive system that provides ad hoc financial remuneration, or the funding source adopted.

Our results seem also to suggest that the national institutional regime is important, but other country-specific factors might be more important for technology transfer activities.

With these findings, our study offers important policy implications that might guide the design and implementation of public policies to sustain technology transfers from academia to industry. On the one hand, our results suggest that the share of university-owned patents has increased significantly (compared with university-invented patents) over the last decade, probably as a consequence of the reforms supporting the adoption of institutional ownership regime. On the other hand, a large share of university/PRO patents remain commercially unexploited. More effort is thus needed to understand barriers to commercialization and find optimal solutions to overcome those barriers. To this point, we note that inventions more intensively rooted in science enjoy higher commercialization outcomes. Therefore, strengthening the university/PRO position may be a fundamental prerequisite of promoting technology transfer. In addition, the incentive systems and financial resources associated with generating the patented invention affect commercialization results; therefore, it is important to implement adequate financial instruments to support technology transfers that address the persistent existence of funding gaps.

Finally, our study contains some limitations that also open opportunities for further research. First, we did not investigate economic success in terms of revenues earned from commercialization activities. Additional research might consider this outcome by employing different indicators of technology transfer performance. Second, our empirical results suggest that ownership regimes can partially explain academic patent commercialization, which in turn implies the importance of other key factors, such as incentive systems oriented toward patent commercialization and technology transfer activities or the availability of financial resources. These results thus expand the implications in terms of human resource management and financial instruments (e.g., proof-of-concept programs, pre-seed and seed funds) as potentially critical drivers of technology transfer that demand further exploration.

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Table 1. University and PRO patents by type of ownership

	Patval II	Patval II	Patval I (Crespi et al., 2010)
N. Countries	22	6	6
Priority dates	2003-2005	2003-2005	1993-1997
University-owned	54%	55%	18%
University-invented	46%	45%	82%
PRO-owned	79%	81%	42%
PRO-invented	21%	19%	58%

Table 2. Commercialized patents by patent ownership

All patents (n=858)	Non-commercialized Patents	Commercialized Patents	Sale	Licensing	Spin-off
University/PRO-owned	66.67%	33.33%	7.65%	25.95%	14.75%
University/PRO-invented	73.14%	26.86%	11.33%	11.97%	14.89%
University patents (n=521)					
University-owned	53.93%	46.07%	13.21%	34.29%	21.79%
University-invented	72.71%	27.39%	12.45%	11.62%	14.52%
PRO patents (n=337)					
PRO-owned	79.93%	20.07%	1.90%	15.24%	7.43%
PRO-invented	75.00%	25.00%	7.35%	13.23%	16.17%

Table 3. Commercialized patents by national IPR ownership regime

All patents (n=858)	Non-commercialized Patents	Commercialized Patents	Sale	Licensing	Spin-off
Institutional Ownership	69.19%	30.81%	7.96%	21.11%	14.47%
Professor's Privilege	67.62%	32.38%	16.19%	14.28%	17.14%
University patents (n=521)					
Institutional Ownership	62.16%	37.84%	11.93%	25.67%	18.01%
Professor's Privilege	64.94%	35.06%	18.18%	13.00%	20.78%
PRO patents (n=337)					
Institutional Ownership	79.29%	20.71%	2.27%	14.56%	9.38%
Professor's Privilege	75.00%	25.00%	10.71%	17.85%	7.15%

Table 4. Multivariate Probit Estimations

	Sale	*Licensing*	*Spin-off*	*Sale*	*Licensing*	*Spin-off*
	(1)	(1)	(1)	(2)	(2)	(2)
University-owned	-0.041	0.648***	0.157	-0.031	0.506***	0.089
	(0.158)	(0.148)	(0.143)	(0.165)	(0.157)	(0.151)
PRO-invented	-0.285	0.310	0.144	-0.203	0.383	0.214
	(0.273)	(0.242)	(0.221)	(0.288)	(0.253)	(0.229)
PRO-owned	-0.876***	0.149	-0.316*	-0.888***	0.227	-0.142
	(0.230)	(0.166)	(0.166)	(0.252)	(0.182)	(0.179)
Institut.ownership regime	-0.420**	0.176	-0.100			
	(0.180)	(0.187)	(0.170)			
FR (instit. regime)				-0.494	-0.340	-0.190
				(0.301)	(0.226)	(0.242)
UK (instit. regime)				-0.071	0.355	0.585**
				(0.278)	(0.255)	(0.247)
JP (instit. regime)				-0.766***	-0.320	-0.218
				(0.290)	(0.220)	(0.232)
US (instit. regime)				-0.252	0.822***	0.629***
				(0.235)	(0.197)	(0.205)
Italy (prof. privilege)				-0.066	0.116	0.043
				(0.267)	(0.238)	(0.251)
Netherlands (instit. regime)				0.053	0.199	0.034
				(0.324)	(0.284)	(0.318)
Small countries (instit. regime)				-0.414*	-0.126	0.151
				(0.250)	(0.202)	(0.206)
Small countries (prof. privilege)				0.442	-0.803*	0.630**
				(0.289)	(0.470)	(0.286)
Published articles (log)	-0.002	0.215***	0.134**	0.013	0.241***	0.149**
	(0.072)	(0.059)	(0.058)	(0.074)	(0.063)	(0.060)
Inventor age (log)	0.315	0.479**	0.584**	0.434	0.359	0.506**
	(0.282)	(0.237)	(0.235)	(0.295)	(0.250)	(0.243)
Research experience (log)	-0.057	-0.081*	-0.110**	-0.068	-0.070	-0.114**
	(0.057)	(0.047)	(0.047)	(0.058)	(0.049)	(0.048)
Financing: EU funds	-0.252	-0.447*	-0.257	-0.356	-0.326	-0.270
	(0.310)	(0.238)	(0.233)	(0.324)	(0.246)	(0.243)
Financing:National programs	0.238	0.013	0.189	0.295*	0.028	0.160
	(0.148)	(0.121)	(0.123)	(0.154)	(0.127)	(0.128)
Financing: Other organ.	0.451**	-0.227	-0.003	0.437**	-0.233	0.015
	(0.186)	(0.190)	(0.183)	(0.191)	(0.197)	(0.187)
Financing: Suppliers	0.595**	0.239	0.019	0.524**	0.227	0.105
	(0.240)	(0.218)	(0.242)	(0.246)	(0.225)	(0.246)
Financing: Loan	0.280	-0.054	-0.089	0.321	-0.176	-0.191
	(0.308)	(0.313)	(0.311)	(0.312)	(0.338)	(0.313)
Financing: Customers	0.507	-3.428	0.333	0.334	-3.491	0.116
	(0.730)	(142.275)	(0.707)	(0.746)	(121.534)	(0.747)
Financing: Other	0.189	-0.029	0.065	0.196	0.043	0.024
	(0.242)	(0.212)	(0.208)	(0.250)	(0.218)	(0.215)
Benefit: Salary	0.529	-0.719	0.802	0.342	-1.067	0.461
	(0.597)	(0.652)	(0.502)	(0.609)	(0.656)	(0.526)
Benefit: Payment	0.469***	1.231***	0.611***	0.412**	1.106***	0.388**
	(0.174)	(0.137)	(0.146)	(0.200)	(0.153)	(0.163)
Benefit: Promotion	-0.603	0.001	-0.258	-0.640	-0.158	-0.457
	(0.393)	(0.237)	(0.266)	(0.413)	(0.256)	(0.282)
Benefit: Other	-0.091	-0.090	0.110	-0.134	-0.191	-0.064
	(0.166)	(0.139)	(0.138)	(0.207)	(0.172)	(0.166)
Technological classes dummies	YES	YES	YES	YES	YES	YES
Constant	-2.339**	-3.165***	-3.042***	-3.023***	-2.477**	-2.795***
	(1.079)	(0.926)	(0.908)	(1.137)	(0.972)	(0.944)
Observations	858	858	858	858	858	858
Log likelihood	-852.800	-852.800	-852.800	-811.025	-811.025	-811.025
Chi-square	269.155	269.155	269.155	324.815	324.815	324.815

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Baseline country in model (2): Germany.

Table S1. Definition and measures of the variables

Variable	Definition
Patent Sale	Dummy variable equal to 1 if the patent has been sold; 0 otherwise. Drawn from the Patval II question: " Was the ownership right to the patent sold to another party not related to the original owner(s) or applicant(s)?"
Patent Licensing	Dummy variable equal to 1 if the patent has been licensed; 0 otherwise. Drawn from the Patval II question: " Has this patent been licensed by (one of) the patent-holder(s) to an independent party?"
Spin-Off	Dummy variable equal to 1 if the patent has used to found a spin-off; 0 otherwise. Drawn from the Patval II question: " Has this patent been used by any of the inventors or applicants to found a new company?"
Commercialized Patent	Dummy variable equal to 1 if the patent has been either sold, licensed, or used to found a spin-off, 0 otherwise.
University	Dummy variable equal to 1 if the inventor is employed by a university, 0 otherwise
PRO	Dummy variable equal to 1 if the inventor is employed by a PRO, 0 otherwise
University-owned	Dummy variable equal to 1 if the patent is developed by an inventor employed by a university and it is owned by the university itself; 0 otherwise.
University-invented	Dummy variable equal to 1 if the patent is developed by an inventor employed by an university and it is not owned by the university itself; 0 otherwise.
PRO-owned	Dummy variable equal to 1 if the patent is developed by an inventor employed by a PRO and it is owned by the PRO itself; 0 otherwise.
PRO-invented	Dummy variable equal to 1 if the patent is developed by an inventor employed by a PRO and it is not owned by the PRO itself; 0 otherwise.
Institut. ownership	Dummy variable equal to 1 if the inventor's country adopted the institutional IPR ownership regime of university patents, and 0 otherwise (e.g. professor's privilege)
Inventor age	Age of the inventor at the time of the invention
Research Experience	Experience of the inventor computed as the difference between the age of the inventor and the year he has started to work as inventor
Published Articles	Number of published articles directly related to the invention
Financing: Internal funds	Dummy variable equal to 1 if the internal funds of the patent applicants has been the major financing source of the research leading to the invention , 0 otherwise (baseline case)
Financing: EU funds	Dummy variable equal to 1 if the European funds of the patent applicants has been the major financing source of the research leading to the invention , 0 otherwise
Financing: National progr	Dummy variable equal to 1 if the national and regional research programs have been the major financing source of the research leading to the invention , 0 otherwise
Financing: Other org.	Dummy equal to 1 if unaffiliated organization joining the project have been the major financing source of the research leading to the invention, 0 otherwise

Financing: Suppliers	Dummy variable equal to 1 if the suppliers have been the major financing source of the research leading to the invention, 0 otherwise
Financing: Loan	Dummy variable equal to 1 if the bank loans has been the major financing source of the research leading to the invention, 0 otherwise
Financing: Customers	Dummy variable equal to 1 if the customers have been the major financing source of the research leading to the invention, 0 otherwise
Financing: Other	Dummy variable equal to 1 if other types of financing have been the financing source of the research leading to the invention, 0 otherwise.

Table S1. (cont.)

Financing: VCs	Dummy variable equal to 1 if VCs and private investors have been the major financing source of the research leading to the invention, 0 otherwise
Benefit: Salary	Dummy variable equal to 1 if it indicates the salary increase has been the benefit received by the inventor as a result of the invention, 0 otherwise
Benefit: Additive salary	Dummy variable equal to 1 if bonus payment in addition to a fixed salary (including the payment for the patent disclosure, application and grant) has been the benefit received by the inventor as a result of the invention, 0 otherwise (baseline case).
Benefit: Payment	Dummy variable equal to 1 if bonus payment in addition to a fixed salary conditioned on the commercial application of the invention has been the benefit received by the inventor as a result of the invention, 0 otherwise.
Benefit: Promotion	Dummy variable equal to 1 if promotions/career advances have been the benefit received by the inventor as a result of the invention, 0 otherwise
Benefit: Other	Dummy variable equal to 1 if other benefits not mentioned have been received by the inventor as the result of the invention, 0 otherwise.
Patent value	Dummy variables: i) perceived patent value top10 if the patent is rated amongst the top 10% most valuable patents in the technological field (baseline case); ii) perceived patent value top25 if it is rated in the top 25%, but not in the top 10%; iii) perceived patent value top50 if it is rated in the top 50%, but not in the top 25%; iv) perceived patent value bottom50 if it is rated in the bottom 50%
Small countries (instit. regime)	Dummy variable equal to 1 if the country of the first inventor is Austria, Belgium, Croatia, Denmark, Greece, Ireland, Israel, Norway, Poland, Spain, and Switzerland, 0 otherwise
Small Countries (prof privilege)	Dummy variable equal to1 if the country of the first inventor is Finland, Hungary, Sweden, and Slovenia
Co-applicant	Dummy variable equal to 1 if the patent has a co-applicant, 0 otherwise
Co-inventor	Dummy variable equal to 1 if other inventor(s) employed by other organizations collaborated with the academic inventor to develop the patented invention, 0 otherwise.
Patent Stock	Patent stock of the patent applicant computed at the priority year of the patent by considering a depreciation rate of 15%
Technological Fields	Six ISI INPI OST Macro Technological Classes: Electrical engineering, Instruments, Chemistry&Pharmaceuticals, Process engineering, Mechanical engineering, and Consumer goods/Construction technologies

Table S2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Commercialized Patent	858	0.310	0.463	0	1
Patent Sale	858	0.090	0.286	0	1
Patent Licensing	858	0.203	0.402	0	1
Spin-Off	858	0.148	0.355	0	1
University	858	0.607	0.489	0	1
PRO	858	0.393	0.489	0	1
University-owned	858	0.326	0.469	0	1
University-invented	858	0.281	0.450	0	1
PRO-owned	858	0.314	0.464	0	1
PRO-invented	858	0.079	0.270	0	1
Institut. ownership	858	0.878	0.328	0	1
University/Pro-owned patent	858	0.640	0.480	0	1
Published articles	858	4.977	35.136	0	1000
Inventor age	858	46.148	11.631	20	82
Research Experience	858	14.288	12.306	0	59
Financing: Internal funds	858	0.429	0.495	0	1
Financing: EU funds	858	0.078	0.268	0	1
Financing: National progr.	858	0.537	0.499	0	1
Financing: other org.	858	0.100	0.300	0	1
Financing: Suppliers	858	0.068	0.251	0	1
Financing: Loan	858	0.031	0.175	0	1
Financing: Customers	858	0.005	0.068	0	1
Financing: Other	858	0.082	0.274	0	1
Financing: VCs	858	0.029	0.168	0	1
Benefit: Additive Salary	858	0.010	0.102	0	1
Benefit: Salary Increase	858	0.204	0.403	0	1
Benefit: Payment	858	0.204	0.403	0	1
Benefit: Promotion	858	0.206	0.405	0	1
Benefit: Other	858	0.057	0.232	0	1
Patent value: top10	858	0.196	0.397	0	1
Patent value: top25	858	0.281	0.450	0	1
Patent value: top50	858	0.242	0.430	0	1
Patent value: bottom50	858	0.281	0.450	0	1
Small countries (instit. regime)	858	0.148	0.355	0	1
Small countries (prof. privilege)	858	0.043	0.203	0	1
Co-applicant	858	0.068	0.251	0	1
Co-inventor	858	0.365	0.482	0	1
Patent Stock	858	283.367	1030.487	0.143	13059.360

Table S2 (cont.)

Austria	858	0.010	0.102	0	1
Belgium	858	0.021	0.143	0	1
Switzerland	858	0.023	0.151	0	1
Czech Republic	858	0.007	0.083	0	1
Germany	858	0.188	0.391	0	1
Denmark	858	0.009	0.096	0	1
Spain	858	0.029	0.168	0	1
Finland	858	0.009	0.096	0	1
France	858	0.155	0.362	0	1
United Kingdom	858	0.065	0.247	0	1
Greece	858	0.006	0.076	0	1
Hungary	858	0.002	0.048	0	1
Ireland	858	0.012	0.107	0	1
Israel	858	0.017	0.131	0	1
Italy	858	0.079	0.270	0	1
Japan	858	0.153	0.360	0	1
Netherlands	858	0.045	0.208	0	1
Norway	858	0.005	0.068	0	1
Poland	858	0.008	0.090	0	1
Sweden	858	0.021	0.143	0	1
Slovenia	858	0.010	0.102	0	1
United Stated	858	0.124	0.329	0	1
Electrical Engineering	858	0.177	0.382	0	1
Instruments	858	0.239	0.427	0	1
Chemistry&Pharmaceutical	858	0.401	0.490	0	1
Process engineering	858	0.092	0.289	0	1
Mechanical engineering	858	0.061	0.239	0	1
Consumer goods/Construction technologies	858	0.030	0.172	0	1

S3 Econometric methods

Given the binary nature of our dependent variables, we employ a non-linear estimation model. The multivariate probit model is the following:

$$\mathrm{Y} = \beta\mathrm{X} + \Sigma$$

where:

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix};\ \beta \begin{pmatrix} b_{1_0}, & b_{1_1}, & b_{1_2}, & \dots, & b_{1_{1l}} \\ b_{2_0}, & b_{2_1}, & b_{2_2}, & \dots, & b_{2_{1l}} \\ b_{3_0} & b_{3_1}, & b_{3_2}, & \dots, & b_{3_{1l}} \end{pmatrix} X \begin{pmatrix} 1 \\ x_1 \\ \vdots \\ x_{1l} \end{pmatrix}, and\ \Sigma \begin{pmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_8 \end{pmatrix}$$

Y is the vector of the three binary dependent variables and X the vector of the explanatory variables for the three equations. These are the same for all the three dependent variables. β is the matrix of the coefficients to be estimated and Σ is the vector of the error terms of the three estimated equations. The use of multivariate probit (MVP) model allows us to estimate jointly a system of equations, meaning the probability of different choices at the same point of time but allowing also for systematic correlations between the choices and controlling for mutual correlation between their errors. Such correlations between uses might be positive (in case of complementarities) or negative (in case of substitutions). In other terms, given an academic patent, we estimate the probability that this patent can be commercialized in one of the three forms indicated.

We also considered alternative models for our estimations. In particular we considered two staged models like hierarchical logistic regression and nested logit regression that in our case would correspond to a first stage indicating the decision to either commercialize or not, and the second stage selecting the commercialization form. However, we did not use these type of models for two reasons. First, the adoption of a hierarchical or a nested model would impose a two stage decisional structure that is not always supported both by the theory and by empirical observation. Second, even if we believe that such decisional structure is in place, our dataset does not provide 'choice variables' specific to the selected form of commercialization that are necessary for these type of models (Greene, 2003; Cameron and Triverdi, 2005). Precisely, the lack of these type variables (uncorrelated to the non-commercialization outcome, and correlated to the commercialization outcome and specific to each type of commercial form) does not allow us to use a hierarchical model. On the contrary, by using the multivariate probit model, which is a generalization of the probit model, we can estimate binary outcomes jointly, also in case of correlated binary outcomes. In our case the multivariate probit model is appropriated also for jointly predicting correlated choices on an individual-specific basis (Greene, 2003; Wooldrige, 2006), without imposing any decisional structure. In addition, differently from multinomial logit that assumes that the errors terms of the choices are independent, multivariate probit relaxes this assumption and allows having correlation between error terms.

A computational drawback of this model is that we are not able to compute the marginal effects of the three outcomes and their combinations. In order to assess the size of the effects of our main variables, we also estimate univariate probit models of the three forms of patent commercialization, with results similar to the ones obtained with the multivariate probit models. We then compute the marginal effects of the explanatory variables in the univariate probit models (see models 7-9 in Table S7).

Table S4. Correlation Matrix

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Commercialized patent	1.00																											
2	Sale	0.47*	1.00																										
3	Licensing	0.75*	0.21*	1.00																									
4	Spin-off	0.62*	0.25*	0.26*	1.00																								
5	University/PRO-owned	0.07	-0.06	0.16*	0.00	1.00																							
6	University-owned	0.23*	0.10*	0.24*	0.14*	0.52*	1.00																						
7	University-invented	-0.05	0.08	-0.13*	0.00	-0.83*	-0.44*	1.00																					
8	PRO-invented	-0.04	-0.02	-0.05	0.01	-0.39*	-0.20*	-0.18*	1.00																				
9	PRO-owned	-0.16*	-0.17*	-0.08*	-0.14*	0.51*	-0.47*	-0.42*	-0.20*	1.00																			
10	Instit. ownership	-0.01	-0.09*	0.06	-0.02	0.18*	0.03	-0.14*	-0.09*	0.15*	1.00																		
11	Inventor age	0.07	0.07	0.05	0.08*	-0.11*	0.00	0.10*	0.03	-0.11*	0.02	1.00																	
12	Inventor experience	-0.05	-0.01	-0.05	-0.01	-0.05	0.01	0.08*	-0.04	-0.06*	0.03	0.61*	1.00																
13	Publication invention	0.09*	0.00	0.10*	0.03	0.03	0.08*	-0.02	-0.02	-0.05	0.01	0.05	0.03	1.00															
14	Financing EU funds	-0.08*	-0.03	-0.07*	-0.04	0.07*	0.00	-0.07*	-0.02	0.07*	-0.04	-0.07*	-0.03	-0.01	1.00														
15	Financing national program	0.07	0.02	0.05	0.06	0.18*	0.10*	-0.15*	-0.07*	0.09*	0.08*	-0.04	-0.02	0.06*	-0.02	1.00													
16	Financing other organization	0.05	0.11*	-0.01	0.02	-0.08*	0.07	0.08*	0.02	-0.15	-0.01*	0.10	0.06*	0.12	0.00	-0.08*	1.00												
17	Financing suppliers	0.04	0.06	0.03	-0.02	-0.02	-0.07*	0.01	0.02	0.05	-0.06	-0.04	-0.04	-0.02	-0.03	-0.15	-0.03	1.00											
18	Financing customers	0.04	0.06	0.01	0.00	-0.07*	-0.01	0.10*	-0.03	-0.06	-0.01	0.06	-0.04	-0.01	-0.03	-0.03	-0.02	0.11	1.00										
19	Financing VCs	0.11*	0.12*	0.05	0.10*	0.04	0.07*	-0.03	-0.03	-0.03	0.04	0.03	0.00	0.00	0.00	-0.02	0.08*	-0.02	0.01	1.00									
20	Financing Loan	0.03	0.04	-0.03	0.02	-0.06	-0.01	0.03	0.04	-0.05	0.03	0.05	-0.04	-0.01	0.04	-0.01	0.03	0.05	0.09*	0.19*	1.00								
21	Financing other	0.01	0.04	0.00	0.02	-0.13*	-0.02	0.11*	0.05	-0.12*	-0.04	0.11*	0.09*	-0.01	-0.07*	-0.24	-0.07*	-0.05	0.02	-0.05	-0.02	1.00							
22	Benefit Salary Increase	0.01	0.05	-0.02	0.05	-0.02	-0.02	0.01	0.01	0.00	0.00	-0.03	-0.01	-0.01	0.01	-0.02	0.00	-0.03	-0.02	0.05*	-0.01	0.01	1.00						
23	Benefit Payment	0.39*	0.12*	0.44*	0.18*	0.14*	0.17*	-0.10*	-0.09*	-0.02	0.05	0.00	-0.07*	0.07*	-0.03	0.02	0.03	0.01	0.04	0.03	-0.03	0.02	0.03	1.00					
24	Benefit Promotion	0.00	-0.04	0.01	-0.03	0.05	0.02	-0.04	-0.02	0.03	0.02	-0.08	-0.03	0.14*	0.02	0.01	0.00	0.09*	0.04	-0.01	-0.02	0.02	0.12	0.00	1.00				
25	Benefit Other	-0.15*	-0.04	-0.18*	-0.02	-0.12*	-0.02	0.07*	0.09*	-0.10*	-0.14*	0.12*	0.09*	-0.03	0.00	-0.03	-0.04	-0.04	0.02	0.06*	0.05	0.04	-0.08*	-0.40	-0.19*	1.00			
26	Patent Stock	-0.06*	0.01	-0.08*	-0.06	-0.12*	-0.11*	0.12*	0.01	-0.01	-0.01	-0.02	0.03	-0.01	-0.01	-0.03	0.08*	0.07	-0.02	-0.03	-0.02	-0.05	-0.02	-0.05*	-0.01	-0.07*	1.00		
27	Co-applicant	-0.03	-0.02	0.00	-0.02	0.03	-0.02*	-0.07	0.06*	0.05*	0.04	0.03	0.03	-0.02	0.01	0.04	0.03	0.00	-0.02	-0.05	-0.02	-0.01	-0.03	-0.01	-0.05	0.02	0.02	1.00	
28	Co-inventor	-0.04	0.06	-0.09	-0.04*	-0.20*	-0.08*	0.17	0.07*	-0.13*	-0.07*	0.02	0.04	-0.02	0.07*	0.00	0.09*	0.03	0.06*	-0.05*	0.02	-0.06*	-0.03	-0.09*	-0.04	0.07*	0.09	0.21*	1.00

(Note: * p<.05)

Table S5. Estimation: University-effect

	Sale	*Licensing*	*Spin-off creation*
	(3)	**(3)**	**(3)**
University/PRO-owned	-0.148	0.449***	-0.003
	(0.148)	(0.131)	(0.127)
Institut. ownership	-0.421**	0.173	-0.092
	(0.178)	(0.184)	(0.169)
University	0.670***	0.337***	0.297**
	(0.175)	(0.125)	(0.127)
Published articles (log)	-0.011	0.200***	0.128**
	(0.072)	(0.059)	(0.058)
Inventor age (log)	0.358	0.516**	0.620***
	(0.281)	(0.236)	(0.234)
Research experience (log)	-0.059	-0.085*	-0.118**
	(0.057)	(0.047)	(0.046)
Financing: EU funds	-0.160	-0.119	0.004
	(0.147)	(0.126)	(0.125)
Financing: National programs	0.191	-0.021	0.204
	(0.155)	(0.131)	(0.132)
Financing: Other org.	0.429**	-0.240	0.013
	(0.187)	(0.191)	(0.184)
Financing: Suppliers	0.560**	0.214	0.003
	(0.239)	(0.218)	(0.243)
Financing : Loan	0.238	-0.105	-0.112
	(0.309)	(0.312)	(0.312)
Financing : Customers	0.513	-3.414	0.296
	(0.729)	(140.437)	(0.714)
Financing : Other	0.143	-0.032	0.090
	(0.250)	(0.218)	(0.216)
Benefit: Salary increase	0.568	-0.671	0.805
	(0.596)	(0.656)	(0.499)
Benefit: Payment	0.469***	1.234***	0.623***
	(0.173)	(0.136)	(0.145)
Benefit: Promotion	-0.570	-0.011	-0.263
	(0.388)	(0.235)	(0.265)
Benefit: Other	-0.096	-0.080	0.130
	(0.166)	(0.139)	(0.137)
Technological classes dummies	YES	YES	YES
Constant	-2.945***	-3.368***	-3.371***
	(1.078)	(0.924)	(0.911)
Observations	858	858	858
Log likelihood	-860.834	-860.834	-860.834
Chi-square	259.284	259.284	259.284

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table S6. Robustness checks

	Sale (4)	*Licensing* (4)	*Spin-off* (4)	*Sale* (5)	*Licensing* (5)	*Spin-off* (5)	*Sale* (6)	*Licensing* (6)	*Spin-off* (6)
University-owned	0.002	0.609***	0.120	0.008	0.571***	0.104	-0.052	0.540***	0.056
	(0.161)	(0.150)	(0.145)	(0.162)	(0.151)	(0.145)	(0.164)	(0.153)	(0.148)
PRO-invented	-0.294	0.265	0.120	-0.294	0.259	0.119	-0.324	0.223	0.122
	(0.275)	(0.246)	(0.222)	(0.276)	(0.247)	(0.223)	(0.281)	(0.252)	(0.228)
PRO-owned	-0.862***	0.070	-0.403**	- 0.855***	0.063	-0.411**	-0.893***	0.024	-0.445***
	(0.234)	(0.167)	(0.168)	(0.234)	(0.168)	(0.168)	(0.236)	(0.170)	(0.171)
Instit. ownership	-0.395**	0.181	-0.100	-0.398**	0.202	-0.093	-0.398**	0.232	-0.067
	(0.182)	(0.189)	(0.169)	(0.182)	(0.190)	(0.169)	(0.184)	(0.193)	(0.174)
Co-applicant	-0.131	0.143	-0.132	-0.126	0.149	-0.132	-0.075	0.184	-0.067
	(0.286)	(0.224)	(0.242)	(0.285)	(0.226)	(0.243)	(0.288)	(0.228)	(0.244)
Co-inventor	0.214	-0.125	-0.086	0.213	-0.098	-0.074	0.213	-0.117	-0.091
	(0.143)	(0.125)	(0.124)	(0.143)	(0.126)	(0.124)	(0.146)	(0.128)	(0.127)
Patent stock				0.000	-0.000*	-0.000	0.000	-0.000*	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Patent value top25							0.167	-0.012	0.048
							(0.199)	(0.158)	(0.156)
Patent value top50							0.143	0.021	-0.240
							(0.208)	(0.168)	(0.171)
Patent value bottom50							-0.211	-0.395**	-0.508***
							(0.217)	(0.173)	(0.176)
Financing (VCs)							0.811**	0.365	0.634**
							(0.322)	(0.314)	(0.282)
Published articles	-0.008	0.210***	0.130**	-0.009	0.208***	0.128**	-0.022	0.193***	0.113*
	(0.072)	(0.060)	(0.058)	(0.072)	(0.060)	(0.059)	(0.074)	(0.060)	(0.060)
Inventor age (log)	0.360	0.459*	0.561**	0.360	0.417*	0.544**	0.366	0.379	0.501**
	(0.288)	(0.239)	(0.236)	(0.289)	(0.240)	(0.237)	(0.293)	(0.243)	(0.243)
Research experience (log)	-0.063	-0.078	-0.104**	-0.065	-0.074	-0.103**	-0.071	-0.074	-0.101**
	(0.057)	(0.047)	(0.047)	(0.057)	(0.048)	(0.047)	(0.058)	(0.048)	(0.048)
Financing EU funds	-0.315	-0.396	-0.201	-0.309	-0.413*	-0.210	-0.337	-0.429*	-0.246
	(0.314)	(0.244)	(0.234)	(0.313)	(0.245)	(0.235)	(0.322)	(0.247)	(0.243)
Financing National progr.	0.273*	0.027	0.215*	0.279*	0.019	0.211*	0.312**	0.034	0.227*
	(0.149)	(0.121)	(0.124)	(0.150)	(0.122)	(0.124)	(0.152)	(0.123)	(0.126)
Financing Other org.	0.441**	-0.257	0.001	0.435**	-0.249	0.008	0.436**	-0.232	0.020
	(0.188)	(0.192)	(0.183)	(0.188)	(0.194)	(0.184)	(0.192)	(0.196)	(0.187)
Financing Suppliers	0.588**	0.274	0.097	0.587**	0.343	0.125	0.626**	0.334	0.124
	(0.243)	(0.220)	(0.242)	(0.243)	(0.225)	(0.244)	(0.248)	(0.227)	(0.248)
Financing Loan	0.231	-0.070	-0.151	0.238	-0.126	-0.171	0.303	-0.091	-0.100
	(0.315)	(0.317)	(0.315)	(0.315)	(0.322)	(0.316)	(0.315)	(0.325)	(0.320)
Financing Customers	0.458	-3.425	0.354	0.461	-3.440	0.340	-0.004	-3.665	0.228
	(0.755)	(123.539)	(0.728)	(0.757)	(120.492)	(0.726)	(0.821)	(111.271)	(0.723)
Financing Other	0.239	-0.009	0.116	0.248	-0.027	0.103	0.350	0.019	0.169
	(0.244)	(0.210)	(0.207)	(0.244)	(0.211)	(0.207)	(0.248)	(0.214)	(0.214)
Benefit: Salary	0.539	-0.617	0.776	0.543	-0.655	0.749	0.414	-0.741	0.591
	(0.608)	(0.630)	(0.492)	(0.609)	(0.626)	(0.491)	(0.639)	(0.631)	(0.502)
Benefit: Payment	0.507***	1.224***	0.615***	0.508***	1.211***	0.608***	0.459**	1.192***	0.586***
	(0.177)	(0.138)	(0.146)	(0.177)	(0.139)	(0.146)	(0.179)	(0.140)	(0.149)
Benefit: Promotion	-0.594	0.011	-0.255	-0.597	0.021	-0.246	-0.584	0.020	-0.281
	(0.397)	(0.242)	(0.273)	(0.396)	(0.243)	(0.273)	(0.398)	(0.244)	(0.282)
Benefit: Other	-0.066	-0.091	0.113	-0.061	-0.122	0.098	-0.137	-0.163	0.042
	(0.167)	(0.140)	(0.138)	(0.167)	(0.141)	(0.138)	(0.171)	(0.143)	(0.141)
Technological classes dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	-2.592**	-3.058***	-2.931***	-2.600**	-2.868***	-2.855***	-2.588**	-2.649***	-2.571***
	(1.102)	(0.935)	(0.911)	(1.104)	(0.940)	(0.913)	(1.133)	(0.962)	(0.947)
Observations	858	858	858	858	858	858	858	858	858
log likelihood	-854.907	-854.907	-854.907	-851.049	-851.049	-851.049	-833.707	-833.707	-833.707
chi-square	272.207	272.207	272.207	272.224	272.224	272.224	298.641	298.641	298.641

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table S7. Marginal effects of univariate probit estimations

	Sale (7)	Licensing (8)	Spin-offs (9)
University-owned	-0.005	0.171***	0.028
	(0.018)	(0.043)	(0.031)
PRO-invented	-0.029	0.083	0.022
	(0.021)	(0.072)	(0.050)
PRO-owned	-0.086***	0.028	-0.070**
	(0.017)	(0.042)	(0.028)
Institut. ownership regime	-0.064*	0.042	-0.021
	(0.033)	(0.039)	(0.037)
Published articles (log)	-0.002	0.051***	0.025**
	(0.009)	(0.014)	(0.012)
Inventor age (log)	0.042	0.115**	0.121**
	(0.033)	(0.057)	(0.048)
Research experience (log)	-0.007	-0.020*	-0.022**
	(0.007)	(0.011)	(0.009)
Financing EU funds	-0.023	-0.083**	-0.040
	(0.026)	(0.038)	(0.037)
Financing National progr.	0.029*	0.001	0.041*
	(0.017)	(0.029)	(0.025)
Financing Other org.	0.070*	-0.059	-0.004
	(0.036)	(0.036)	(0.036)
Financing Suppliers	0.091*	0.067	0.012
	(0.054)	(0.064)	(0.052)
Financing Loan	0.039	-0.014	-0.022
	(0.053)	(0.072)	(0.055)
Financing Customers	0.068		0.074
	(0.156)		(0.204)
Financing Other	0.030	-0.001	0.018
	(0.037)	(0.050)	(0.045)
Benefit: Salary increase	0.120	-0.105	0.230
	(0.149)	(0.067)	(0.180)
Benefit: Payment	0.066**	0.388***	0.152***
	(0.030)	(0.048)	(0.042)
Benefit: Promotion	-0.047**	0.001	-0.047
	(0.018)	(0.058)	(0.041)
Benefit: Other	-0.007	-0.019	0.028
	(0.019)	(0.033)	(0.029)
Technology class dummies	YES	YES	YES
Observations	858	858	858
Log likelihood	-223.063	-331.548	-321.857
Chi-square	72.010	200.389	75.731

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

S8. Additional robustness checks

We performed additional checks of the robustness of our results not reported in the paper.

First, estimation model (1) in Table 4 of the paper simultaneously assesses the effect of patent ownership of universities and PROs and of the national university IPR ownership regime on the likelihood of commercializing patents. In unreported regressions we also estimate separately the variables indicating University and PRO ownership, excluding the national regime without relevant changes in the results. Similar results are obtained if we only include the national regime. Results are available from the authors.

We also made some controls of our variables. In particular, property changes occurring in patent sales and licensing of co-owned patents could also be affected by country-specific laws. Moreover, property changes might occur among co-applicant of patents. However, we find that there are only a few cases of co-applicants of patents that are licensed or sold and their distribution is quite dispersed across countries. In our sample, we only have 12 patents licensed with a co-applicant: 3 in Germany, 1 in Finland, 3 in France, 1 in Italy, and 4 in US. Concerning patents sold in presence of a co-applicant they are distributed as follows: 1 in Germany, 1 in Finland, 1 in Norway, and 1 in US (Total 4 patents). These frequencies might confirm that, in our case, property changes in sale transactions and licensing negotiations are not affected by country-specific laws and multiple ownership of patents.