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Universities look beyond the patent policy discourse in their intellectual property strategies

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Abstract

In recent years, much emphasis has been placed in the policy discourse on the patenting of academic research outcomes. However, universities produce a wide variety of IP, not all of which is suitable to be patented, or which universities may choose not to patent. The present article, building upon an original survey of 46 universities (about 27% of total) in the United Kingdom, investigates universities' knowledge transfer processes through the exchange of a variety of forms of IP: patents, copyright, open source and non-patented innovations. The analysis concerns: (i) the extent to which universities exchange these forms of IP; (ii) whether they are used in a complementary or substitute way; and how relatively (iii) strategic effective and (iv) market efficient they are, in allowing universities to reach certain objectives (relating to knowledge transfer, competitive positioning, innovation and financial gain). We find that most universities perceive a variety of types of IP to be effective, usually in order to reach different strategic objectives. Certain forms of IP are use more than others for particular purposes, and no IP exchanges in the marketplace are exempt from institutional problems. Our results challenge the Bayh-Dole Act (now adopted in many OECD countries and elsewhere); i.e. whether patents and patent markets are the best tool for knowledge dissemination from research base into use, and other benefits, and whether instead it would be more appropriate to encourage universities to a variety of IP.

Key words: intellectual property rights (IPR), universities, academic patenting, Bayh-Dole, institutional economics.

JEL classification: O34, O31, O32, D23, D02.

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Introduction: looking beyond patents

Universities are increasingly considered to be important contributors to the "knowledge economy" (Quah, 1998) and to national competitiveness. The provision of higher education (the transfer of knowledge to society by increasing human capital) and the production of new, cutting-edge research, are still regarded as the key functions of the university in the twenty-first century. At the same time, however, universities are increasingly required to engage in the direct transfer of their research outputs, in the form of new technologies and new intellectual property (IP), to economic partners such as firms and other organizations (Göransson et al, 2009). The metaphor of the university as an "ivory tower" where academics perform research in isolation, without interacting with external stakeholders, is no longer considered tenable: instead, active engagement in knowledge transfer has become a "third mission" for university institutions.

The best way in which universities should accomplish their knowledge transfer objectives is debated by academics and policymakers. A growing body of research investigates the determinants and success of different models of knowledge transfer, analyzing the nature of the relationships through which new knowledge is produced and transmitted. Knowledge transfer can take place either through "open science" channels (conferences and publications, where the results of publicly-funded research are publicly disseminated), through direct collaborative relationships (joint ventures, contract research, consultancies, as well as sharing of research facilities and equipment), through employment-based channels (graduate recruitment, secondments at universities, exchange of personnel between industry and academia), and through the licensing or sale of university-owned patents.

Another approach to investigating knowledge transfer involves exploring how universities exchange knowledge embedded in intellectual property rights (IPR) documents and in other intellectual property (IP) contracts. The literature that looks at the protection and exchange of university-produced IP mostly investigates patents and/or publications as alternative systems of dissemination. It has been pointed out that there are partial incompatibilities between the two systems, which have been explored at some length in the literature (Blumenthal et al, 1986; Eisenberg, 1996).

However, universities produce a wide variety of IP, not all of which is suitable to be patented and which cannot be codified in the form of scientific publications either. Universities may also choose not to patent even if they could in principle do so. Some authors have recognized that the exchange of IP that is not embedded in patents but that is traded via other types of contracts (such as copyright, open source, confidentiality agreements, or simply non-protected innovations) is quantitatively very important for organizations (Klevorick et al, 1987) and for universities in particular (Landry et al, 2007). The use and exchange of these forms of IP on the part of universities is nonetheless under-explored in the literature investigating university-industry knowledge transfer (Baghurst et al, 2009).

The present article, building upon the original UKNOW survey (see section 3 for details) of 46 universities (about 27% of full population) in the United Kingdom, makes a contribution towards filling this analytical gap.

Going beyond the narrow focus on patents and publications that characterizes most contemporary literature, the analysis concerns: (i) the extent to which universities exchange a variety of different forms of IP, not limited to patents and to openly

disseminated knowledge codified in publications, but also include open source and non-patented inventions; (ii) whether these forms of IP are used in a complementary or substitute way; and whether some of these are more (iii) effective and (iv) efficient in order to reach certain strategic benefits (relating to knowledge transfer, competitive positioning, innovation and financial gain) .

The article is organized as follows. In section 2, we argue that, in order to improve our understanding of how universities use their intellectual property (IP) for value creation (including knowledge transfer, competitive positioning, innovation and financial gain), it is important to capture a variety of types of IP market transactions (patents, copyright, open source and no protection). Also, we need to investigate the extent to which such transactions happen efficiently, in terms of what obstacles universities encounter in the IP marketplaces. In the context of this discussion, we present the research questions that we address. In section 3 we present the data, and in section 4 we present our analysis and the results. In section 5 we conclude and add some implications of our results for policy.

2. Intellectual property management in universities: issues and research questions

A large body of literature has been developed, especially in recent years, which looks at the relative importance of different models of knowledge transfer, often linked to different types of research processes that generate new knowledge. These processes can take place exclusively within the university as a result of public funding, within the university but with full or partial funding from the private sector, or in collaboration between universities and firms or other organizations. Correspondingly, knowledge transfer can take place either through "open science" channels (conferences and publications, where the results of publicly-funded research are publicly disseminated), through direct collaborative relationships (joint ventures, contract research, consultancies, as well as sharing of research facilities and equipment), through employment-based channels (graduate recruitment, secondments at universities, exchange of personnel between industry and university), and through the licensing or sale of university-owned patents.

When seen from the perspective of firms, the relative importance of these models varies. The literature has shown that most firms prefer to access university knowledge through open science channels, employment relationships, and collaborations. Use (buying and licensing) of university-owned patents generally tends to rank low in importance for this purpose (Bruneel et al, 2009; Cohen et al, 2002; Mowery and Sampat, 2005; Póvoa and Rapini, 2010). Numerous empirical studies have also pointed out that firms' interactions with university depend upon size (larger firms have more collaborations), R&D intensity (more R&D intensive firms collaborate more, thanks to their greater absorptive capacity), distance (but the latter is not always important and not for all firms), technological sector (Agrawal and Henderson, 2002; Bekkers and Bodas Freitas, 2008; Póvoa and Rapini, 2010)

When investigated from the perspective of universities, it has been argued that these different models are appropriate to different disciplines and different types of institutions, as well as to different institutional and cultural contexts (Litan et al, 2007, Perkmann et al, 2010)). Generally, universities derive more income from collaborative research, including contract research and consultancy, than from

licensing of patents (D'Este and Perkmann, 2007) and university income from patent licensing is generally very skewed (Blake, 1993), more so than in other industries (Hicks et al., 2001).

Nonetheless, in recent years, much emphasis has been placed in the policy discourse on the patenting of academic research outcomes, on the basis of the view that university ownership of patents facilitates the codification of academic knowledge in a form that can be more easily used and commercially exploited by industry (Berman, 2008). On the one hand, since the approval of the Bayh-Dole act in 1980, numerous countries have passed legislation allowing universities to claim patents on the results of publicly-funded research, including those countries where it was previously customary to assign the ownership of IP to the faculty that had invented it (Geuna and Nesta, 2006). Following this wave of regulations (Crespi et al, 2006), the number of patents filed by universities has increased (Geuna and Nesta, 2006; Lissoni et al, 2009). On the other hand, the performance of university institutions in terms of knowledge transfer is increasingly measured on the basis of indicators tracking the intensity with which they patent their research results: frequently used performance indicators are the number of patents filed and licensed, the income from patent licensing activities, the number of academic spinout companies created in order to exploit university patents (see e.g. HEFCE, 2007). This provides a strong incentive for the application of this model of knowledge transfer (Allan, 2001; Sorensen and Chambers, 2008).

However, universities produce a wide variety of IP, not all of which is suitable to be patented (or which universities may choose not to patent even if they could in principle do so) and which cannot be codified in the form of scientific publications either. Baghurst et al (2009) distinguish between "hard" IP, which can be protected through patents, and "soft IP" which is generally not patented. These forms of IP are very important, for example, for those universities whose knowledge base resides primarily in the social sciences and in the arts and humanities.

As pointed out by Baghurst et al (2009), despite the importance of soft IP for universities, the issues relating to its generation, identification, commercial exploitation and value are systematically under-explored. While there have been some studies on the complementary use of different forms of IP protection, these have generally involved sectors other than universities. Moreover, most studies on alternative IP protection mechanisms focus only on proprietary IP, looking at the role of trademarks, design registrations, copyright (Graham and Somaya, 2006; Ramello and Silva, 2006) and neglecting non-proprietary forms of IP[1]. Only a few case studies have aimed at uncovering how software firms use both open source and patents as part of their commercial strategies (Campbell-Kelly and Garcia-Swartz, 2008). Moreover, with some exceptions, most of the literature assumes that different IP protection mechanisms are substitutes rather than complements, despite the lack of evidence in this respect (Nelson, 2006; Teece, 2006).

Such lack of attention for the variety of forms of IP that universities can use has not

[1] In the following analysis, we use the term "proprietary IP" (or, equally, intellectual property rights, IPR) for IP upon which restrictions on use, sharing, copying and modification are enforced by legal means (namely, patents and copyright), and "non-proprietary IP" for IP on which some or all of these restrictions are relaxed (namely, open source and non-patented innovations). This classification differs from that used by Baghurst et al (2009) who use the term "hard IP" to refer to patents, and "soft IP" to all other types of intellectual property protection mechanisms.

only characterized the academic literature of knowledge transfer. It has been argued that universities themselves, and policymakers, have not paid enough attention to the existence and need for different models of IP protection that go beyond the use of patents and publications. Macdonald (2009) argues that most universities have adopted a model of technology transfer that is typical of the pharmaceutical industry, one of the heaviest users of the patent system. However, in most other industries (such as in software and electronics) firms exploit their technological advantage through trade secrets, marketing strategy and lead times, rather than through patents (Klevorick et al., 1987): a model of knowledge transfer based on patent licensing from universities is unlikely to fit these firms' business models. Consequently, university managers tend to overvalue patents, while they should be focusing instead on different procedures, methods, and goals for differing industries (Macdonald, 2009).

The empirical analysis presented in this article, building upon an original survey of university technology transfer offices in the United Kingdom, allows us to contribute to this area of analysis.

First, considering a variety of forms of IP that are exchanged by universities, we investigate whether universities use them in a complementary or substitute way, by exploring two research questions:

(i) whether more than one form of IP (patent, copyright, open source IP, and non-patented technical invention) is exchanged at the same time (the variety of IP used is discussed in section 4.2), and

(ii) whether different forms of IP are used for different strategic objectives of the universities (knowledge transfer, competitive positioning, innovation and financial gain) or whether they are used for the same objective (the complementarity or substitution between different forms of IP is discussed in section 4.3)

Second, we consider the ways in which the exchange of IP stimulates the wealth creation process from IP, and we investigate two further research questions:

(iii) which forms of IP do universities find more effective, in terms of conferring certain benefits (this is discussed in section 4.4); and

(iv) which forms of IP do they find more efficient to use (i.e. universities find less market obstacles when exchanging that form of IP) (this is discussed in section 4.5).

The UKNOW survey (see section 3) providing the data for this analysis, asked universities not only to describe which of four forms of IP they exchange (indicated in the left column of Table 1), but also which specific governance forms they use in order to carry out such IP exchanges (indicated in the right column).

Table 1. Marketplaces and governance forms investigated through the UKNOW survey

Forms of IP	*Governance structures*
Patents as a tool for the protection of novel ideas	Selling patents Buying patents Out-licensing patents In-licensing patents Cross licensing patents Participation in patent pools

Copyright as a tool for the protection of original creative expressions	Selling copyright Buying copyright Out-licensing copyright In licensing copyright
Open source' IP as a tool for the protection of original ideas and creative expressions	Participating in open source software development Participating in open source pharmaceutical projects Participating in other open source communities
'Non patented' innovations	Releasing not patented product or process innovations to the public Releasing not patented product or process innovations to private firms Using not patented product or process innovations Collaborating with universities without patent restrictions

In order to investigate the extent to which these forms of IP are used in a complementary or substitute way, we analyze the strategic objectives that underpin the universities' exchange of each form of IP, that is the benefits that they seek from these exchanges. The identification of such benefits is based on a review of the economic literature, where motivations for engaging in holding and exchanging IP have been investigated mostly with respect to patents. Some studies have looked in detail at the determinants of engagement in open source development (David and Shapiro, 2008) but very few have investigated motivations in a comparative perspective.

It has been argued that patenting promotes innovation because it allows the inventor to invest more financial resources in research (Arrow, 1962), thus developing more and better technology; and conversely, the acquisition of patents allows the buyer to use the best technology available. Patent licensing enables standardization and compatibility among technologies (Merges and Nelson, 1990; Plant, 1934), while patent exchanges in general allow to build strategic relationships with or within industry (Jaffe et al, 1993; Teece, 1986), which furthers innovation diffusion. Patents also have a wide range of direct and direct economic benefits. Not only the exchange of patents can be a direct source of income, but patents can be held or exchanged for strategic purposes, in order to influence the process of competition (Mazzoleni and Nelson, 1998).

There are at several economic reasons why firms file or acquire patents (Graham and Sichelman 2008). Firms can file patents for defensive purposes, in order to stop others from imitating their product (Rivette and Kline, 2000; Cohen et al., 2000; Granstrand, 1999), but they can also use them offensively, in order to block competitors from using certain technologies, or as bargaining chips in cross-licensing negotiations. Other ways in which patents can increase one's market share at the expense of competitors include the attempt to drive up the competitors' costs, to gain access to their technologies, to prevent them from acquiring patents on the same inventions, or even to push them out of the market. Patents are also used for financial purposes, for example to increase one's chances to secure investment, to be acquired or taken public in an initial public offering, or just to increase the value of one's assets in bankruptcy (Coriat and Orsi, 2002; Rivette and Kline, 2000); for signalling purposes, in that patents can be interpreted as a proxy for internal capabilities and assets; and for reputation purposes, since patents can serve as assets that increase the value of the firm and of its brand (Grassman, et al 2009). On the other hand, the registration and maintenance of IPRs require the payment of fees that can constitute a significant

financial burden especially for small enterprises: involvement in open source and in exchanges of non-patented innovations therefore can confer economic benefits in terms of ability to cut costs.

We have summarized the main motivations for exchanging IP, as identified by the literature. They are divided into 13 possible strategic benefits, and are listed in the right-hand column of Table 2. The organizations that responded to the UKNOW survey were asked to tick the five most important.

Table 2. Strategic benefits investigated through the survey

Type of strategic benefit	*Specific benefit*
Knowledge transfer	Building informal relationships with industry networks Increasing ability to enter collaborative agreements Giving something to the community
Competitive positioning	Increasing market share Professional recognition or brand recognition; Competitive signalling
Innovation	Using the best inventions, innovations, creative expressions Making or using compatible technology or creative expressions Developing better technology or creative expressions Benefiting from user or supplier involvement as a development strategy
Financial gain	Direct income from market transactions Cost cutting Increasing ability to raise venture capital

These benefits capture the broad ways in which universities exchange flows of knowledge and financial resources with external organizations (listed in the left-hand column of table 2). On the one hand we have direct knowledge flows from university to external sources, firms or government (which we term "knowledge transfer") and the diffusion of university knowledge through market mechanism and through creating market awareness (which we term "competitive positioning"); on the other hand, we have flows of knowledge that feeds back into universities' innovation processes (which we term "innovation") and financial gain from firms and other organizations to universities.

Finally, we investigate which IP mechanisms universities find more effective (i.e. better at conferring certain strategic benefits, see Table 2) and more efficient (i.e. universities find less obstacles when exchanging that form of IP in the marketplace). So far the literature has mostly focused on the advantages and limitations of patents in stimulating or hampering these flows: therefore, extending this analysis to other forms of IP is an original contribution. To do so, we combine an analysis of the strategic benefits that universities seek from different forms of IP, with an analysis of the obstacles that they encounter when exchanging IP.

The identification of these obstacles is based on a review of the literature and of industry reports. The main problems identified often concern the negotiation and enforcement of IPR contracts: it is difficult to value patents and to define their boundaries (Merges and Nelson, 1990), and the patent's value usually depends on its intended utilization, thus making it difficult to negotiate an appropriate price for it (Mansfield et. al., 1981; Hall and Ziedonis, 2001). Negotiations are complicated also by unbalanced bargaining power, asymmetric information and lack of trust, since opportunistic behaviour is common in business dealings (Bachmann, 2006). Even when contracts can be made, enforcing them is costly, both in terms of direct legal costs and in terms of business costs of litigation. Enforcement problems have also been studied with respect to open source, where it has been pointed out that

difficulties rise when the licensee fails to comply with the terms and conditions set by the licensor, for example by appropriating and closing up the source code (merging it with new code and releasing it in a proprietary way, such as "all rights reserved") or by failing to apply the same terms and conditions to derivative works (Montagnani, 2009). Other problems, which have been identified for example with respect to the software industry (IBM 2006) have to do with lack of transparency in the marketplace (difficulty to identify the owner, uncertainty as to what the right price is, impossibility to make sense of text and diagrams in patent documents), lack of integrity (poor behaviour and unjust court cases), and low patent quality (too many similar patents with no inventive step, which in turn makes it difficult for firms to assess their degree of novelty and understand their economic value). Such obstacles to value creation have also been discussed in Bessen and Meurer (2005).

Universities that responded to the UKNOW survey were asked to tick the five most relevant obstacles (from the list of 14 possible obstacles presented in Table 3) when exchanging each type of IP.

Table 3. Obstacles investigated through the survey

Type of obstacle	*Specific obstacle*
Search problems	Difficulty in locating the owners of IP Difficulty in locating the users of IP Difficulty in finding the best IP
Lack of transparency	Difficulty in assessing the degree of novelty/originality of the IP Lack of clarity of the IP document Difficulty in assessing the economic value of the IP
Contract negotiation	Difficulty in negotiating a price for the IP Difficulty in negotiating the terms, not related to price, of the contract
Contract enforcement	Excessive cost of enforcing the contract Problems, not related to cost, with enforcing the contract Trust issues (opportunistic behaviour, free-riding, or similar)
Regulation and practices	Different practices of firms Regulations allow too exclusive rights International IP regulations do not fit the needs of different local markets

3. Data overview

The empirical analysis is based upon the data collected through an empirical survey of a sample of universities, colleges and public research organizations based in England, Scotland, Wales or Northern Ireland. For simplicity, we refer to this sample as to "UK universities", as less than 25% of the sample (and of the set of respondents) are non-university institutions. The UKNOW survey[2] was carried out between October 2008 and March 2009. The survey was targeted to technology transfer offices and similar units within the institution. The respondents within such units usually possess a broad view of their institution's involvement in IP exchanges, as a large share of the contracts governing IP transactions are managed by their offices. Consequently, they have experience of the obstacles encountered when attempting to exchange such IP efficiently, and they have some knowledge of the relative strategic advantages of the

[2] The UKNOW survey was designed and carried out at Birkbeck College (under the coordination of Birgitte Andersen) under Work Package 3.2: "An IPR Regime in Support of a Knowledge Based Economy", as part of the UKNOW *(Understanding the Relationship between Knowledge and Competitiveness in the Enlarging EU')* project of the EU 6th Framework Programme (contract number CIT 028519).

different forms of IP as a consequence of the interactions with the researchers themselves.

The sample of relevant institutions, and of their respective technology transfer offices, was created by merging the list of 120 members of the University Companies Association (UNICO), which represents the technology exploitation companies of UK universities, and the list of 162 institutions that responded to the HEBCI 2004-05 and 2005-06 surveys (HEFCE, 2007), which includes all the 133 universities in the UK, as well as some colleges of higher education and public research organizations. After correcting different spellings and eliminating double entries, a final population of 169 different organizations was assembled. Respondents had a choice of different options through which they could answer the survey: filling in the questionnaire available online; returning an electronic copy of the questionnaire by email; returning a copy of the questionnaire by post or fax. We obtained 46 valid responses (27.2% response rate).

The questions referred, separately, to four proprietary and non-proprietary marketplaces governing the exchange of IP: patents, copyright, open source and non-patented innovations. In turn, for each marketplace, the questions referred to different IP governance structures, as detailed in Table 1.

A first set of questions allowed us to collect information on the extent and intensity with which universities participate in the various IP marketplaces and governance structures. Respondents were asked about their stock of patents owned and licensed, whether they engaged in each patent governance form, and if so the number of transactions they performed in the last two years. With respect to open source, non-patented technology and copyright, universities were asked whether they engaged in each governance form, and if so the number of transactions they realized in the last two years.

A second set of questions referred to the benefits that university technology transfer offices seek when trading IP. For each marketplace and governance form, respondents were presented with a list of 13 strategic benefits (listed in Table 2) among which they were asked to tick up to five that they deemed most important.

Respondents were then asked about the obstacles they encountered when trading IP. They were presented with a list of 14 obstacles (listed in Table 3) among which they were asked to tick up to five that they deemed of highest impact.

Finally, respondents were requested to provide some general information about the organization: geographic localization, ownership (independent or subsidiary), size (current number of employees, current yearly turnover), research intensity (yearly expenditure in R&D), geographic extension of the organization's main market (domestic or international), and sector of activity.

A few additional variables relating to organizational characteristics were derived from other sources. In particular, the number of academic staff and total staff (academic, non-academic, atypical) of the institution (relative to 2007/08), the share of academic staff employed in scientific fields (engineering and technology, medicine and natural sciences, in the same period), and the income of the institution were drawn from HESA's (the Higher Education Statistics Agency) database. The year of foundation of the technology transfer office and the number of staff employed within were drawn from the 2007 HE-BCI survey (HEFCE, 2007).

4. Analysis

4.1. Representativeness of respondents

The organizations in the sample possess different institutional and historical features. Most are universities, some are university colleges or other institutions of higher education (such as music conservatoires and arts colleges), and a few are public research organizations. Table 4 compares the distribution of institutions in the overall sample and in the sets of respondents and non-respondents, across several main characteristics: geographical localization, size (in terms of academic staff employed), institutional type, both with respect to status and to historical origin (distinguishing between universities, other higher education institutions and public research organizations, and further subdividing universities into 5 categories according to the period in which they were founded[3]). The distribution of respondents by geographical localization, institutional type and size in terms of total staff (academic, non-academic and atypical) is representative of the overall sample (p-values of the t-tests for the subsets of respondents and non-respondents are reported in brackets).

Table 4. Structure of sample and respondents

		sample (169)	*respondents (46)*	*non-respondents (123)*
		%	%	%
geographic localization	England	82.2	89.1 (0.264)	79.7 (0.580)
	Wales	5.3	4.3 (0.791)	5.7 (0.893)
	Scotland	11.2	6.5 (0.351)	13 (0.648)
	Northern Ireland	1.2	0 (0.461)	1.6 (0.749)
	Total	*100*	*100*	*100*
Type	"old" universities	5.9	8.7 (0.501)	4.9 (0.701)
	"red brick" universities	17.8	26.1 (0.208)	14.6 (0.480)
	"plate-glass" universities	13.6	15.2 (0.781)	13 (0.882)
	"former polytechnics"	20.7	19.6 (0.865)	21.1 (0.929)
	"modern" universities	16.6	8.7 (0.185)	19.5 (0.518)
	university colleges	16.6	8.7 (0.185)	19.5 (0.518)
	public research organizations	7.7	13 (0.259)	5.7 (0.505)
	Other	1.2	0 (0.461)	1.6 (0.749)
	Total	*100*	*100*	*100*
size (total staff)	<500	10.7	4.3 (0.194)	13.0 (0.537)

[3] The categories are the following: "old" universities (founded before the mid-XIX century); "red brick" universities (founded between the mid-XIX century and the mid-XX century); "plate glass" universities (founded between the 1960s and the end of the 1980s); "former polytechnics" (institutions formerly designated "polytechnics" which changed their status to universities in 1992); "modern" universities (founded after 1992, not formerly designated "polytechnics").

	500-1000	13.0	10.9	13.8
			(0.486)	(0.728)
	1000-5000	47.3	56.5	43.9
			(0.197)	(0.497)
	>5000	24.3	28.3	22.8
			(0.923)	(0.960)
	Missing	4.7	0.0	6.5
			(0.134)	(0.513)
	Total	*100*	*100*	*100*

4.2. Variety of IP exchanged by universities

We first investigate research question (i) concerning whether universities exchange more than one form of IP (patent, copyright, open source IP, and non-patented technical invention) at the same time.

Of the 46 respondents, 13 do not exchange any of the four forms of IP considered. Of the respondents that exchange IP, only 10 (30%) exchange just one form, while most (23, that is 70%) exchange two or more (9 exchange two different forms of IP, 10 exchange three, and 4 exchange all four). In particular, 9 organizations (27%) only exchange proprietary forms of IP (patents and/or copyright), two organizations (6%) exchange only non-proprietary IP, while most use a combination of proprietary and non-proprietary forms of protection of their IP (22 organizations, or 67%). This suggests that most universities exchange a variety of forms IP, both proprietary and non-proprietary.

According to a Probit regression on the set of 46 respondents, the choice as to whether to exchange IP (of any kind) is significantly affected by the presence of an internal technology transfer office: having internal competences in technology transfer increases the probability to exchange IP with external organizations. Being a public research organization has a positive effect on the likelihood to exchange IP, while being a college of higher education has a negative effect. As the former organizations in our sample tend to be specialized in medicine and biotechnology, while the latter specialize in the arts, their different likelihood to exchange IP may be due to their disciplinary specializations. However, the share of academic staff in science and technology has a negative effect on the likelihood to exchange IP. It may be that, once we control for the subset of public research organizations, those universities that have a larger share of academic staff in science and technology prefer to rely on dissemination systems based on traditional open science channels rather than on the transfer of IP. Finally, the age and size of the institution in terms of academic staff, as well as the type of university institution in terms of historical origins, do not significantly affect the choice to exchange IP.

Table 5. Probit regression on the choice to exchange IP

	Coefficient Estimates	*Std. Error*	*z value*	*Pr(>|z|)*
(Intercept)	0.999(***)	0.255	3.910	0.000
Age	-0.001	0.001	-0.950	0.349
Number of academic staff	0.000	0.000	0.325	0.747
Presence of TTO	0.337(*)	0.186	1.810	0.079
Share of academic	-0.834(**)	0.332	-2.515	0.017

staff in science & technology				
Public research organization	0.562(*)	0.296	1.896	0.066
University college	-0.698(**)	0.326	-2.139	0.039
Former polytechnic	0.308	0.242	1.275	0.211
“Old” university	0.470	0.377	1.249	0.220
“Red brick” university	0.082	0.226	0.364	0.718
”Plate glass” university	0.087	0.259	0.337	0.738
n. observations	46			
Log-likelihood	-18.39895			
AIC	60.798			

Signif. codes: p<0.01 ‘***’ p<0.05 ‘**’ p<0.1 ‘*’

Considering the subset of 33 universities that exchange IP, the number of different forms of IP that they exchange is, according to a Poisson regression whose results are reported in Table 6, positively affected by size in terms of academic staff. A greater number of academic staff may indicate greater variety in terms of disciplines offered and hence greater likelihood to exchange different forms of IP. Age per se has a negative effect on the variety of IP that is exchanged, however being a “old” university founded before 1850 has a positive effect. As old universities tend to be more research oriented and also to be less specialized, this may indicate that these universities produce a wider variety of research outcomes. Also being a former polytechnic has a positive effect on the number of different forms of IP that are exchanged. Although these universities are generally not very research intensive, they tend to dedicate a lot of effort to interactions with businesses and other external organizations, which may explain the greater variety of IP exchanged. Being a university as opposed to another type of institution, has a negative effect on the likelihood to exchange IP. Finally, having an internal technology transfer office has no significant effect on the variety of IP exchanged.

Table 6. Poisson regression on the variety of IP exchanged

	Coefficient Estimates	*Std. Error*	*z value*	*Pr(>|z|)*
(Intercept)	4.693 (***)	1.364	3.441	0.003
Age	-0.005 (*)	0.002	-1.913	0.070
Number of academic staff	0.000 (**)	0.000	2.740	0.013
Presence of TTO	0.113	0.432	0.262	0.796
Share of academic staff in science & technology	0.116	0.995	0.116	0.909
University	-1.868 (*)	1.027	-1.819	0.084
Public research organization	-1.140	1.424	-0.800	0.433
University college	-1.414	1.343	-1.053	0.305
Former polytechnic	1.542 (**)	0.590	2.615	0.017
“Old” university	2.435 (**)	0.890	2.735	0.013
“Red brick” university	0.845	0.574	1.473	0.156
”Plate glass” university	0.607	0.710	0.855	0.403
England	-1.791 (**)	0.728	-2.460	0.023

n. observations	33
Log-likelihood	-33.26807
AIC	94.536

Signif. codes: p<0.01 '***' p<0.05 '**' p<0.1 '*'

The greater size of the institution allows it to broaden the scope of its activities and exchange a variety of IP[4]. If we consider the distinction between exchanges of proprietary IP and exchanges of non-proprietary IP, we find (from the descriptive statistics shown in Table 7) that universities that use only proprietary or only non-proprietary IP are smaller, in terms of income and staff, than those that use both types. Universities that exchange only non-proprietary IP are less involved in the sciences (their share of academic staff in medicine, engineering and technology and natural sciences is smaller); while those that use both proprietary and non-proprietary marketplaces are on average larger (both in terms of income and number of staff) and have a larger number of technology transfer staff, than all other groups.

Table 7. Distribution of university characteristics according to participation in proprietary and non-proprietary IP marketplaces

	average income	*average number of staff*	*year of foundation*	*average number of TT staff*	*average share of academic staff in science*
at least one IP marketplace (n=36)	19,562,964	4,795.00	1884	36.00	0.44
only proprietary (n=9)	12,286,669	1,745.56	1884	24.00	0.31
only non-proprietary (n=2)	48,114	880.00	1932	16.00	0.18
both proprietary and non-proprietary (n=22)	21,646,031	5,526.36	1879	43.09	0.38

In sum, we find that most organizations that exchange IP use a variety of forms of IP, often both proprietary and non-proprietary. Greater variety in the exchange of IP appears linked to organizational characteristics such as younger age, larger size and being a certain type of institution (specifically, being a older university or a former polytechnic).

4.3. Complementarity between different forms of IP

In order to explore research question (ii), we investigate whether the various forms of IP are used in order to reach the same objectives (that is, they are used as substitutes)

[4] If, in the regression whose results are presented in Table 6, we consider, instead of the number of academic staff, the number of total staff present in the institution (not just academic but also administrative and technical) this has an even stronger positive effect on the likelihood to exchange IP.

or whether they are used to reach different objectives (that is, they complement each other).

Table 8 summarizes the answers given by respondents with respect to the benefits that they derive from exchanging different forms of IP. Columns do not sum to 100% since universities could tick more than one benefit. Shares greater than 50% are highlighted.

Table 8. Benefits from exchange of various types of IP

	patent	*Copyright*	*open source*	*non-patented innovations*
Respondents in each IP marketplace	29	15	12	18
	%	%	%	%
KNOWLEDGE TRANSFER	65.5	66.7	83.3	72.2
Building informal relationships with industry networks	58.6	53.3	58.3	0.0
Increasing ability to enter collaborative agreements	48.3	40.0	58.3	50.0
Giving something to the community	17.2	20.0	58.3	55.6
COMPETITIVE POSITIONING	27.6	66.7	16.7	44.4
Increasing market share	10.3	40.0	0.0	5.6
Professional recognition or brand recognition	17.2	33.3	16.7	27.8
Competitive signalling	6.9	6.7	0.0	11.1
INNOVATION	31.0	46.7	58.3	61.1
Being able to use the best creative expressions	6.9	6.7	33.3	22.2
Benefiting from user or supplier involvement as a development strategy	0.0	33.3	25.0	16.7
Providing an opportunity to make or use compatible creative expressions	20.7	6.7	41.7	55.6
Innovation methodology: developing better creative expressions	13.8	13.3	33.3	16.7
FINANCIAL GAIN	65.5	66.7	0.0	50.0
Direct income from market transaction	58.6	60.0	0.0	44.4
Cost cutting	6.9	13.3	0.0	5.6
Increasing ability to raise venture capital	37.9	13.3	0.0	11.1

The objective to transfer knowledge to industry and other stakeholders is the main reason for universities to exchange all forms of IP, and particularly non-proprietary IP. The specific benefits relating to knowledge transfer however differ according to

the form of IP that is exchanged: open source and non-patented innovations are exchanged in order to increase the university's ability to enter collaborative agreements and to give something to the community, while patents and copyright particularly allow universities to build informal relationships with industry networks.

The other types of benefits are even more specific to certain forms of IP. Benefits relating to competitive positioning are particularly sought when exchanging copyright, while benefits relating to innovation are particularly sought when exchanging open source and non-patented innovations (non-proprietary IP) and benefits relating to financial gain (in the form of direct income) are particularly sought when exchanging patents and copyright (proprietary IP).

As the choice of different benefits is associated to the exchange of different forms of IP, these results suggest that such forms of IP are complementary rather than substitutes for one another. This is supported by the analysis of the specific IP governance forms that universities engage in. Most universities are active in selling and/or out-licensing patents and copyright, while very few buy or in-license them[5]. By selling and out-licensing patents and copyright, universities transfer knowledge to external agents (in the case of copyright, they also promote knowledge diffusion via market mechanisms) and receive flows of financial resources. When universities and public research organizations exchange non-proprietary IP, instead, they tend to both release and acquire it[6]. By participating in open source communities and by releasing and using non-patented innovations, universities transfer knowledge to external agents, and receive flows of knowledge that are important for their own innovation processes.

4.4. The presumed effectiveness of different forms of IP in reaching strategic benefits

In order to analyze which forms of IP are regarded as relatively more effective in reaching various strategic benefits, addressing research question (iii), we quantify the presumed relative comparative advantage of each form of IP (each "IP marketplace"), and of each governance form (see Table 1) through which IP is exchanged, in reaching a certain benefit, relative to the others.

[5] Of the 29 organizations that engage in the patent marketplace, most (28) engage in out-licensing patents, and many (17) are active in selling patents, while comparatively few engage in in-licensing (5) buying (4) cross-licensing (5) or participating in patent pools (4). Universities tend to file their own patents rather than in-license them from other organizations, since the total stock of in-licensed patents is a small fraction (about 7%) of the total stock of owned patents. The organizations using copyright were not requested to detail their involvement in the various governance forms for copyright, but simply to state whether they engaged in registering their copyright. From their choices of benefits and obstacles in each governance form, however, we find that at least 9 are active in selling copyright, at least 3 in buying copyright, at least 12 in out-licensing copyright and at least 6 in in-licensing copyright. As in the case of patents, selling and out-licensing are the most frequent forms of engagement in this kind of proprietary IP marketplace.

[6] All of the 12 organizations that are active in open source do so in the field of software, while 3 are also active in open source pharmaceuticals and 3 in other open source communities. Of the 18 organizations that engage in markets for non-patented technology, most are active in most of the different governance forms: releasing non-patented technology to the public (15) or to private firms (12), using non-patented technology (16) and collaborating with other universities without patent restrictions (15).

To do so, we develop a "revealed marketplace advantage" (or "revealed governance advantage") index that measures the importance of a benefit in a certain marketplace (or governance form) relative to the importance of the same benefit across all marketplaces (or governance forms)[7]. This index only assumes positive values: a value that is greater than 1 indicates that that marketplace (or governance form) is regarded as particularly important at stimulating a certain benefit, while the opposite holds when the value is less than 1.

Table 9 provides an overview of results of revealed marketplace (RMA) and governance (RGA) advantage indexes, computed for the four types of knowledge and resource flows identified[8]. Values of the index greater than 1 are highlighted.

Table 9. 'Revealed advantage index' for the various benefits

Marketplace / governance form	*RMA / RGA index*			
	Knowledge transfer	*Competitive advantage*	*Innovation*	*Financial gain*
Patents	0.64	0.23	0.63	1.38
Selling patents	0.95	1.20	0.51	1.21
Buying patents	0.00	6.81	0.00	0.00
Out-licensing patents	1.10	0.80	0.90	1.04
In-licensing patents	0.80	1.24	2.09	0.54
Cross licensing patents	0.98	0.76	1.91	0.65
Participation in patent pools	0.98	0.00	1.91	0.98
Copyright	0.50	0.42	0.72	1.08
Selling copyright	1.06	0.91	0.63	1.21
Buying copyright	0.58	1.16	2.43	0.58
Out-licensing copyright	0.98	0.98	1.14	0.98
In licensing copyright	1.16	1.16	0.61	0.87
Open source	0.97	0.17	1.41	0.00
Participating in open source software development	1.01	1.21	0.94	n.a.
Participating in open source pharmaceutical projects	0.00	0.00	2.56	n.a.
Participating in other open source communities	1.28	0.00	0.85	n.a.

[7] In more rigorous terms, let x_{ij} be the number of times that benefit i is chosen in marketplace (or governance form) j, and $\sum_i x_{ij}$ the number of times that any benefit is chosen in marketplace (or governance form) j; let $\sum_j x_{ij}$ be the number of times that benefit i is chosen in all marketplaces (or all governance forms), and $\sum_i \sum_j x_{ij}$ the total number of times any benefit is chosen across all marketplaces (or all governance forms). Then, for a certain marketplace (or governance form), the revealed marketplace advantage RMA (or revealed governance advantage RGA) index is: $RMA/RGA = (x_{ij}/\sum_i x_{ij})/(\sum_j x_{ij}/\sum_i \sum_j x_{ij})$. That is, the index is the ratio between the share of benefit i in marketplace (or governance form) j and the share of benefit i in all marketplaces (or all governance forms).

[8] In order to compute the RGA and RMA indexes, the universities' responses with respect to the specific benefits (as listed in Table 2) have been aggregated into the four main categories indicating the types of benefits which universities seek through the trade of various forms of IP (also listed in Table 2: "knowledge transfer", "competitive positioning", "innovation" and "financial gain").

Non-patented innovations	0.59	0.31	1.03	0.88
Releasing not patented product or process innovations to the public	1.01	1.40	0.92	0.77
Releasing not patented product or process innovations to private firms	0.90	0.93	0.92	1.35
Using not patented product or process innovations	0.90	0.93	1.31	0.77
Collaborating with universities without patent restrictions	1.17	0.61	1.02	1.00

Universities particularly seek financial gain when exchanging patents and copyright (and particularly when selling IPR, and out-licensing patents). Instead, universities particularly seek innovation benefits when exchanging non-patented innovations (especially when using non-patented technology and collaborating with other universities), and when engaging in open source. Knowledge transfer, instead, is enhanced to a similar extent by the exchange of all forms of IP.

To provide a quantitative measure of the extent to which specialization in seeking a certain benefit is concentrated in one or a few marketplaces or whether a benefit is equally sought in different marketplaces we consider the coefficient of variation of the RMA index ($|\sigma_{RMA}/\mu_{RMA}|$). Similarly, for governance forms we use the coefficient of variation of the RGA index ($\sigma_{RGA}/\mu_{RGA} \cdot 100\%$). The coefficients of variation are reported in Table 10.

Table 10. Coefficients of variation across governance forms and marketplaces

Index of governance / marketplace specialization	*Knowledge transfer*	*Competitive advantage*	*Innovation*	*Financial gain*
Patents: $\|\sigma_{RGA}/\mu_{RGA}\|$	50.37	138.45	71.57	59.68
Copyright: $\|\sigma_{RGA}/\mu_{RGA}\|$	26.90	12.21	71.01	28.77
Open source: $\|\sigma_{RGA}/\mu_{RGA}\|$	88.38	173.21	66.14	n.a.
Non-patented innovations: $\|\sigma_{RGA}/\mu_{RGA}\|$	12.83	33.71	17.83	28.07
All forms of IP: $\|\sigma_{RMA}/\mu_{RMA}\|$	30.72	39.70	37.26	71.12

There is high variability in the index, showing that most categories of benefits are quite specific to certain forms of IP, and to certain governance forms. The exception is, once again, the fact that knowledge transfer is more equally sought across all marketplaces. Also, innovation benefits are sought to a similar extent across all non-patented governance forms, and competitive advantage benefits are sought to a similar extent across all copyright governance forms.

These results highlight three main patterns regarding the universities' presumed effectiveness of different forms of IP in reaching various strategic benefits: (a) proprietary forms of IP are relatively more used in order to enhance flows of financial resources; (b) non-proprietary forms of IP are relatively more used effective in order to enhance knowledge feedback flows (fostering the universities' own innovation processes); (c) all forms of IP are similarly used in enhancing knowledge transfer flows from university to industry.

Since enhancing knowledge transfer is a very important objective across all forms of IP exchanges (as shown in Table 8) and no type of IP confers a relative advantage in enhancing this flow (as shown in Table 9), it is interesting to investigate whether other features, such as certain organizational characteristics, are particularly correlated to the choice of this objective. Table 11 reports the results of a regression that explains the choice of knowledge transfer benefits on the part of the 33 universities that exchange IP, using as regressors the various types of IP they exchange and a set of organizational control variables (age, presence of an internal technology transfer office, number of staff engaged in technology transfer, type of institution).

Table 11. Probit regression explaining the choice of knowledge transfer benefits

	Coefficient Estimates	*Std. Error*	*z value*	*Pr(>|z|)*
(Intercept)	-0.345 (*)	0.196	-1.761	0.093
Patent	0.493 (**)	0.176	2.805	0.011
Open source	0.363 (***)	0.113	3.198	0.004
Copyright	0.218 (*)	0.108	2.022	0.056
Non-patented innovations	0.082	0.119	0.684	0.502
Age	0.002 (***)	0.001	3.545	0.002
Presence of internal TTO	0.551 (***)	0.131	4.210	0.000
Number of staff in technology transfer	0.003	0.002	1.662	0.111
University college	0.139	0.314	0.441	0.664
“Old” university	-0.476 (**)	0.192	-2.476	0.022
“Plate glass” university	-0.071	0.142	-0.504	0.620
”Former polytechnic”	-0.007	0.116	-0.058	0.954
n. observations	33			
Log-likelihood	7.965			
AIC	10.069			

Signif. codes: p<0.01 ‘***’ p<0.05 ‘**’ p<0.1 ‘*’

As expected, the exchange of all forms of IP is positively related to the likelihood to choose knowledge transfer benefits (although the coefficient for the variable indicating the exchange of non-patented innovations is not significant). Older universities in general seem to be more likely to choose knowledge transfer benefits than younger ones. This may indicate that younger and more commercially oriented institutions may be less interested in knowledge transfer (and more interested in financial gain or competitive positioning). There is no strong effect of the type of institution on the likelihood to choose knowledge transfer benefits: the only exception is the set of “old” universities founded before 1850 which are also less likely to choose these benefits. It may be that old universities, which are more research oriented, prefer to transfer knowledge using the traditional scientific publications channels, and instead use IP transactions for other objectives.

Finally, universities that have an internal technology transfer office are significantly more likely to seek to enhance knowledge transfer by exchanging IP. This may suggest that having dedicated internal facilities for technology transfer is instrumental in enhancing knowledge transfer flows.

4.5. The experienced efficiency of different IP marketplaces

Having discussed the use of different forms of IP by universities in enhancing certain types of benefits, our dataset also allows us to explore the extent to which they can do so efficiently, addressing research question (iv). In practice, we explore what obstacles universities encounter when exchanging different forms of IP through different governance forms. Focus is on the intensity with which universities face various obstacles when exchanging different forms of IP, and the relative significance of certain obstacles in each IP marketplace and IP governance form.

Table 12 summarizes the answers given by respondents with respect to the obstacles they encounter when exchanging different forms of IP. Columns do not sum to 100% since universities could tick up to five obstacle. Shares greater than 40% are highlighted.

Table 12. Obstacles to the exchange of each form of IP

	patent	*Copyright*	*open source*	*non-patented innovations*
Respondents in each IP marketplace	29 %	15 %	12 %	18 %
SEARCH	37.9	13.3	33.3	33.3
Difficulty in locating owners of IP/ technology developers who do not enforce IP	6.9	13.3	8.3	11.1
Difficulty in locating the users of IP/technological solutions	27.6	6.7	16.7	27.8
Difficulty in finding the best IP or technological solution	13.8	0.0	25.0	5.6
TRANSPARENCY	48.3	60.0	33.3	44.4
Difficulty in assessing the degree of originality of the IP or technological solution	31.0	20.0	0.0	22.2
Description or drawing in the IP document is not clear / difficulty in understanding non-patented technological solutions as they are not formally documented	0.0	0.0	8.3	16.7
Difficulty in assessing the economic value of the IP or technological solution	44.8	53.3	25.0	33.3
CONTRACT NEGOTIATION	41.4	46.7	8.3	38.9
Difficulty in negotiating a price for the IP or technological solution	27.6	46.7	0.0	38.9
Difficulty in negotiating the terms (not related to price) of the exchange contract	31.0	13.3	8.3	16.7
CONTRACT	27.6	26.7	33.3	27.8

ENFORCEMENT				
Excessive cost of enforcing the exchange contract	10.3	20.0	0.0	16.7
Problems (not related to cost) with enforcing the exchange contract	6.9	0.0	8.3	5.6
Trust issues (e.g. opportunistic behaviour, free-riding, or similar)	0.0	6.7	25.0	11.1
REGULATION AND PRACTICES	3.4	20.0	8.3	5.6
Differences in practices of firms	10.3	6.7	16.7	0.0
Regulations allow too exclusive rights	0.0	0.0	8.3	5.6
International IP regulations do not fit the needs of different local markets	3.4	13.3	8.3	5.6

All obstacles are found in all marketplaces, although the intensity with which they are experienced varies. In the case of proprietary IP, the most frequent obstacles involve lack of transparency, and particularly the difficulty in assessing the economic value of IPR (44.8% of respondents engaged in the patent marketplace, and 53.3% of respondents engaged in the copyright marketplace), followed by contract negotiation issues (46.7% report difficulties in negotiating a price for copyright). While in the theoretical literature IPR exchange is often assumed to be perfectly transparent and characterized by a perfect flow of information, it seems that in real IPR marketplaces organizations encounter numerous problems. This is consistent with results from the empirical literature (Cockburn, 2007).

Also in the case of non-patented innovations, universities mostly find problems relating to lack of transparency and contract negotiation: assessing the economic value of IP and negotiating a price for it are important to 33.3% and 38.9% respectively). Instead, in the case of open source universities indicate problems with search (25% encounter difficulties in finding the best open source projects), lack of transparency (25% find it difficult to assess economic value) and contract enforcement (25% find it difficult to trust the other parties involved; this is probably related to the risk that open source participants may appropriate and close up the source code, or fail to apply the same terms and conditions to derivative works). Thus, the risk of opportunistic behaviour in the open source marketplace appears to be quite high.

The same obstacles are found with similar intensity when exchanging patents, copyright and non-patented innovations, while in the case of open source other obstacles are prevalent. This is confirmed by the analysis of the relative importance of certain obstacles when exchanging specific forms of IP, performed by computing an index similar to the "revealed marketplace advantage" index mentioned earlier, only this time with respect to obstacles. Hence, we call it "revealed marketplace

disadvantage" index (RMD)[9]. The RMD index calculates the experienced significance of an obstacle in a certain IP marketplace relative to the overall significance of this obstacle across all IP marketplaces. The results are reported in Table 14.

Table 14. "Revealed disadvantage index" for the various obstacles

Form of IP	*RMD index*				
	Search	Transparency	Contract negotiation	Contract enforcement	Regulation
Patents	1.16	0.97	1.08	0.93	0.41
Copyright	0.39	1.15	1.16	0.85	2.24
Open source	1.39	0.91	0.30	1.52	1.33
Non-patented technology	1.08	0.95	1.08	0.99	0.69
All marketplaces: $\lvert\sigma_{RMD}/\mu_{RMD}\rvert$	42.89	10.64	45.02	28.47	69.66

In the case of patents, copyright, and non-patented innovations search and contract negotiation obstacles are relatively more important (transparency and contract negotiation in the case of copyright). In the case of open source, the obstacles that are relatively more important are transparency, contract enforcement and regulation (most of the obstacles reported concern open source software, which is probably the area where universities have the greatest experience). The coefficient of variation of the RMA indicates that obstacles are generally specific to forms of IP, with the exception of transparency problems (mainly related to the difficulty in assessing the economic value of IP) which are similarly important for all forms of IP.

As universities encounter obstacles with similar intensity across all forms of IP, none of these forms of IP appears to be more efficient than the others. To some extent, there are differences in which obstacles are relatively more important for certain forms of IP, suggesting that further investigations into the problems that universities encounter when exchanging different forms of IP can provide useful indications to policymakers who wish to intervene to improve the functioning of these marketplaces.

5. Conclusions

While most of the analyses of the ways in which universities transfer knowledge to the economic system focus either on their use of patents or on their use of traditional knowledge dissemination channels based on publications, the empirical analysis developed in this article focuses on a variety of forms of IP.

Our evidence suggests that most universities that exchange IP rely on a variety of forms of IP. This is especially so for larger universities, for universities that focus on a wider variety of disciplines and have greater research intensity or greater business orientation.

[9] In order to compute the RGD and RMD indexes, the universities' responses with respect to obstacles have been aggregated into five main categories ("search", "transparency", "contract negotiation", "contract enforcement", "regulation").

Universities derive specific and different benefits from the exchange of different forms of IP, suggesting that they complement each other. While the fact that universities still seem to patent only a small part of their discoveries is sometimes attributed to their lack of awareness and to their inability to use these instruments, the result that we have presented, however, suggest that alternative channels for the transfer of IP are used because they confer specific advantages that are not obtainable by patenting.

In particular, proprietary forms of IP are relatively more used in generating financial benefits to universities, while non-proprietary forms of IP are relatively more used in enhancing the flows of knowledge from industry to university, fostering the universities' own innovation processes. All forms of IP are used in order to transfer knowledge.

Universities that particularly seek to transfer knowledge from the exchange of IP are older and have internal technology transfer competencies. The underlying rationale for the implementation of regulations creating incentives for universities to protect their IP through patents and copyright was to encourage dissemination of knowledge (Berman, 2008; Schacht, 2005). However we found that also non-proprietary marketplaces offer universities important opportunities to build and strengthen relationships with industry and with the wider community. Since universities very often choose to embed their knowledge outcomes in forms of IP that are different from both patents and publications, like open source and non-patented technology, and they do so in order to transfer knowledge to industry, these forms of non-proprietary IP cannot simply be assumed to be less efficient than patents in knowledge transfer. Indeed, our results challenge whether patents are actually the best tool for knowledge dissemination (as suggested by Bayh-Dole) or whether instead it would be more appropriate to encourage universities to use non-proprietary marketplaces more intensively than proprietary ones.

Universities encounter obstacles when exchanging all forms of IP: none of these exchanges appear to be particularly efficient. The exchanges of patents, copyright and non-patented innovations are mainly affected by similar problems. Hence we do not find support for the claim that embedding knowledge into IPRs "automatically" generates efficient markets, since exchanges of IPRs are affected by the same problems as exchanges of non-patented innovations. Such problems are not easily solved by interventions aiming at strengthening the market institutions, but may be intrinsic to marketplaces where knowledge goods are traded. Instead, open source communities appear to be mainly affected by a different set of problems. Because obstacles are very often IP marketplace-specific and IP governance-specific, these policies should not be "one size fits all" but tailored to specific forms of IP and to specific types of transactions.

Therefore, better understanding of the processes of knowledge transfer from academia to other economic agents such as industry, and conversely also of knowledge and financial gains flow from industry to academia via feedback processes, requires policy, management and research to take into account a greater variety of forms of IP than have been considered so far (focusing especially on the participation in open source communities and on the exchange of non-patented innovations).

Also, information on the engagement in open source projects and on the exchange of non-patented innovations is not typically collected by those surveys that seek to quantify the amount of invention or knowledge transfer performed by universities and

other related variables. By neglecting these channels, however, we risk missing an important part of the knowledge transfer process.

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