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WORKING PAPER SERIES

INTELLECTUAL PROPERTY GOVERNANCE AND KNOWLEDGE CREATION IN UK UNIVERSITIES

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Working paper No. 16/2010

Università di Torino

Intellectual Property Governance and Knowledge Creation in UK Universities

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A version of this paper is forthcoming in Economics of Innovation and New Technology

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Abstract

The public discourse advocating increased patenting of academic discoveries, which has led to the approval of legislative measures (such as the Bayh Dole Act, which is now adopted world-wide in various forms) is based on a set of theoretical arguments, mainly related to knowledge transfer and financial reward. Using an original survey of 46 universities (about 27%) in the United Kingdom, we investigate whether some of these arguments are supported by evidence. We focus on the extent to which patents, as opposed to other forms of intellectual property (IP) protection mechanisms, enhance knowledge circulation, and especially contribute to universities' own knowledge creation processes. We also investigate whether universities consider the markets for ideas and creative expressions to function efficiently. We find that universities use all forms of IP intensively in order to transfer their knowledge to industry or government. However, they mainly rely on non-proprietary IP (open source and no-patent strategies) when aiming to enhance their own knowledge creation processes. Also, universities do not find that markets for patents or copyrights function more smoothly than non-proprietary IP marketplaces. The results challenge the orthodox theories on the rationales for patents and other proprietary intellectual property rights (IPRs). Thus, we question the assumptions and arguments underpinning the implementation of patents on academic research outcomes via political reforms since the 1980s.

Key words: Universities, knowledge creation, intellectual property governance, academic patenting, copyright, open source, Bayh Dole Act.

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

Acknowledgements: The data collection has been funded by the UKNOW project ("Understanding the Relationship between Knowledge and Competitiveness in the Enlarging EU") of the EU 6th Framework Programme 2006-2009 (contract number CIT 028519). The analysis has also been partly funded through a consultancy project for the UK Intellectual Property Office on the development of an analytical framework for the flow of knowledge from the research base into use - with the specific intention of testing the effective and efficient use of formal IPRs and 'soft IP' in the United Kingdom (April-September 2010). We would also like to acknowledge Joaquin Azagra-Caro, Sjoerd Hardeman, Patrick Llerena, Julien Penin, and the other participants for productive discussion at the AnCoRA workshop ["The economic analysis of knowledge production in academia"] in Strasbourg, July 2010. Finally, we would like to thank the three anonymous reviewers for their valuable comments in the shaping of this paper.

1. Introduction

Universities are increasingly considered important contributors to the knowledge economy and to national competitiveness. While the provision of higher education is still regarded as their key function, increasing importance is attributed to their role in the direct transfer of new knowledge, in the form of new technologies and new intellectual property (IP), to economic partners such as firms, governments, and other stakeholders. The emphasis on the economic role of the university as a producer of knowledge that feeds into innovation processes builds on numerous theoretical developments that have taken place since the 1980s, including: the economic debate on knowledge-driven economic growth (Lucas 1988; Romer 1990); the literature on the features of the "knowledge economy", which, it has been argued, is characterized by faster rate of technological progress and by greater economic importance of industries which produce and trade knowledge products, including the university sector (Quah 1998); and the debate in economic geography, where it has been claimed that universities play a key role in regional economic development through collective learning processes (Lawton-Smith 2007).

While the important role that universities play in the production of new knowledge and in its transfer to the economic system is now widely shared and acknowledged, the best way in which such knowledge transfer should take place is debated. At least since the 1980s, policymakers have supported the view that intellectual property rights (IPRs) – such as patents, formally registered copyright, trademarks, and other protection mechanisms where restrictions on using, sharing, copying and modifying intellectual property (IP) are implemented by legal means – are required for university-produced knowledge to be transferred effectively. It has been argued that the possibility to commercialize their own IP and to derive income from these activities would induce universities to be more proactive in disseminating their knowledge to the economic system (Mowery et al. 2001), especially at a time of shrinking public budgets for higher education (Geuna and Muscio 2008).

The view that supports more intensive use of IPRs on the part of universities rests on a broad set of arguments not limited to the traditional justification for their enforcement, which is to provide incentive for sufficient private investment in innovation (Dasgupta and David 1994). It has in fact been claimed that IPRs are instrumental in facilitating the circulation of knowledge in the economic system, including enhancing the flows of knowledge between universities and other organizations such as firms and government agencies. These claims, which we review in the next section, underpin well-known policy initiatives directed at expanding and strengthening the application of IPRs to the outcomes of publicly-funded research.

The Bayh-Dole Act implemented in the United States in 1980 is an early and very influential example of legislation encouraging universities to patent the outcomes of their research activities. The Act gave US universities control of their inventions and other IP resulting from federally-funded research, and encouraged the use of patent protection. This was believed to be the best mechanism for (among other things) providing an economic incentive for companies to pursue further development and commercialization of government sponsored R&D through corporate ventures between and among the research community, small businesses and industry (Schact 2005). Other legislation further extended the scope and duration of IPR protection: the Cooperative Research Act of 1984 allowed universities to grant exclusive patent licenses up until the life of the patent, while previously, exclusive licenses were

possible only for five years from the first commercial sale or eight years from the patent date, which ever was shorter (Feldman and Stewart 2006). Obstacles to the commercial exploitation, on the part of firms, of research findings that originated at public laboratories were progressively removed (thanks to the Stevenson-Wyndler Act of 1980 Act and the Federal Technology Transfer Act of 1986). Legislation aimed at similar objectives and including similar provisions has later been adopted in many other countries around the world (Crespi, Geuna and Verspagen 2006). For example, in Europe, regulations that assign universities ownership of intellectual property arising from government-funded research and the right to commercialize the results obtained have been recently introduced (with varying degrees of stringency) in the Flanders (1998), Denmark (2000), Germany (2002), Austria (2002) as well as Norway (2002) and Finland (2007). Italy is the only country that has bucked the trend, awarding ownership rights to faculty employees in 2001 (Mowery and Sampat 2005).

In the UK, universities have had rights to their employees' IP since 1985 (Macdonald 2009) but it was only after the UK Department of Trade and Industry published a white paper called Realising our Potential (DTI 1993), calling for universities to play a key role in national innovation and competitiveness, that they began to increase their patenting activity. This has continued in the following 15 years, as a number of policy reports and guidelines (described in Tang 2008) have continued to push universities to adopt a more "commercial" model of interaction with external stakeholders.

Following the introduction of these measures and the establishment in most institutions of technology transfer offices (TTOs) that often pursue aggressive patenting policies, there have been increases in the number of university-owned patents (Geuna and Nesta 2006) and in universities' income from royalties (AUTM 2002; Feller 1990). However, the success and implications of these measures are controversial.

The main objective of this article is to assess whether the theoretical arguments that promote the patenting of academic research outputs are supported by empirical evidence. Such evidence is derived from an original survey of universities in the United Kingdom developed under the EU-funded project UKNOW ("Understanding the Relationship between Knowledge and Competitiveness in the Enlarging EU"), 2006-2009. See section 3 for details of the survey data.

The first research question which drives the analysis (whose theoretical background is explained in the next section) investigates whether the exchange of IPRs between university and industry can enhance knowledge circulation (and particularly stimulate the universities' own knowledge creation processes) to a greater extent than the exchange of other forms of IP that do not enforce proprietary restrictions[1].

Furthermore, the new-institutional literature (which underpins the arguments in favour of privatizing ideas or creative expressions via IPRs) suggests that IPRs solve the market failure normally attached to such non-rival goods by promoting the creation of efficient "markets for knowledge" (for an overview of this argument, see

[1] In the following analysis, we classify forms of IP according to the extent to which there are restrictions on using, sharing, copying and modifying it: we use the term "proprietary IP" (or, equally, intellectual property rights, IPRs) for IP on which such restrictions are enforced by legal means (for example, patents and copyright), and "non-proprietary IP" for IP on which some or all of these restrictions are relaxed (for example, open source and non-patented innovations).

Arrow 1962, Andersen 2004, Antonelli 2005). Thus, the next question addressed in the paper addresses if markets for IPRs work better, or more smoothly, for value creation compared to market exchanges of non-proprietary IP.

The rest of the article is structured as follows. In section 2, we present a conceptual framework that illustrates how different forms of IP (patents, copyright, open source IP and innovations with no protection) flow between universities (as well as public research organizations) and the commercial sector (private firms, but also government agencies and charities), and we present the research questions for subsequent analysis. By mapping the theoretical incentives behind the IP flows in our framework of analysis, we characterize the rationales that have been used to justify the increased implementation of IPRs on academic research outcomes. The literature on the advantages and drawbacks of academic patenting is also discussed in this section. In section 3, we present the structure of the empirical investigation in terms of the data, variables identification and empirical research design. In section 4 we present and discuss the results of the empirical analysis of the universities' contribution to knowledge circulation in the economy, and especially the role of IP governance for knowledge creation processes within universities. The effectiveness of IP marketplaces for this purpose is also analysed. In section 5 we draw some conclusions.

2. Intellectual Property (IP) and knowledge flows between universities and the commercial sector

2.1. A conceptual framework to illustrate university-industry knowledge flows

Numerous contributions from the law and economics literature have provided theoretical arguments that justify the use of patents as a means not only to foster innovation by providing incentives for private agents to invest in research and development (Arrow 1962), but also as a means to stimulate the circulation of knowledge in the economic system through the creation of efficient markets for knowledge-based ideas, remedying the market failure normally attached to non-rival goods (Verspagen 2006). It is this second strand of literature that provides a theoretical framework supporting the implementation of measures encouraging universities to patent their discoveries, even when the latter have been produced as the results of publicly-funded research.

In fact, it is argued that basic research activities suffer from market failures that generally cannot be overcome by the enforcement of property rights to the knowledge that they produce (Nelson, 1959; Mowery, 1983). Basic research activities are characterized by uncertainty (Nelson, 1959), since the inventor cannot completely calculate neither the probability of invention success, nor the risk of being unable to exploit the idea effectively, nor the extent of the demand for the invention once it has been commercialized; so the risk-averse may decide against investing resources in research, despite the possibility to protect its outcomes. Moreover, basic research activities often generate results that open up many more opportunities than those that individual organizations can realistically exploit (Arrow 1974; Nelson 1959). It has also been pointed out that the patent system may not guarantee full appropriability: in fact, "a patent does not prevent anyone from thinking about the patented idea, and through pure inspiration produce a different competitive product not embodying or rewarding the original idea" (Andersen 2004, 425). In the presence of uncertainty and

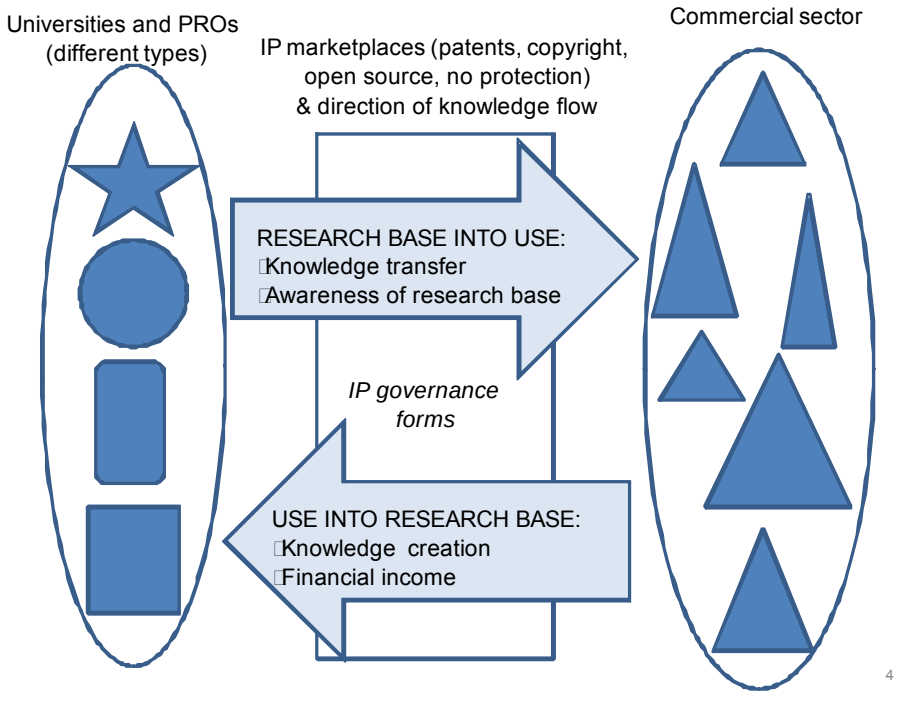
weak appropriability conditions, incentives for private investment in knowledge production remain low even within a strong IPR regime.

Given that the instantiation of IPRs is not sufficient to induce private agents to engage in a socially optimal amount of basic research activities, public funding remains necessary. To this end, a government can engage directly in knowledge production, making it freely available for use - as in the government research system - or it can offer public subsidies to academic institutions, requiring them to openly disseminate their findings in the public domain - as in the academic research system (Dasgupta and David 1994).

Therefore, other rationales are advocated in order to support the patenting of the outcomes of publicly-funded university research. We can summarize them in a framework that links the use of IPRs to the enhancement of knowledge and financial resource flows between universities and other organizations, such as firms and government agencies (see Figure 1).

Figure 1 illustrates how different forms of IP (patents, copyright, open source IP and technology with no protection) flow between universities (as well as public research organizations) and the commercial sector (including private firms but also government agencies and charities). The flows of knowledge and financial resources take place through market exchanges of IP relying upon a variety of governance forms, such as different licensing forms (out-licensing, cross-licensing, patent pools etc.) or participation in open source communities.

Figure 1. Flows of knowledge and financial resources between universities and the commercial sector



There are two directions in which knowledge and financial resources flow. One direction goes from the university's research base into commercial use, in the form of "knowledge transfer" and "awareness of research base". The other direction goes

from the commercial sector to the university, in the form of "knowledge creation" (that is, feedback from industry which enhances the university's own knowledge creation processes) and "financial resources".

The arguments supporting the increased use of patents and other IPRs suggest that they enhance all of these four flows. Although these arguments have been developed in general terms in relation to IPRs, we have in this paper subsequently applied and tested them in relation to the specific use of various forms of intellectual property (patents, copyright, open source, no patent protection strategies) on the part of universities. Together they complement the traditional "innovation incentives rationale" for IPRs, suggesting that implementing IPR protection can promote not only knowledge production, but also knowledge disclosure and communication. We review these arguments below.

IPRs are assumed to enhance the circulation of knowledge between economic agents:

This is due to several reasons. It has been argued that IPRs provide direct incentives for sharing ideas and expressions through trade, due to the creation of markets for knowledge-based ideas (Antonelli 2005). Through IPRs, it is possible for the creator of an idea to exclude others from using it, opening the possibility for wider commercial exploitation (Rivera-Batiz and Romer, 1991). Therefore, IPRs are able to create a market for technology and creative expressions, and, as ideas and expressions face increasing return to scale by nature, this give rise to increasing rent or profit as markets expands. One important assumption upon which this argument depends is that IPR markets function efficiently. According to the theory, the instantiation of knowledge into an IPR document transforms it into a "commodity" whose features can be understood by all the parties in the exchange and for which an efficient price able to regulate demand and supply can arise "automatically". This way, a market exchange will take place and the knowledge embedded in the IPR will be transferred to the buyer that values it the most, which presumably is also the buyer that is best able to develop it in order to derive some economic gain.

Another way in which licensing and trade of IPRs is thought to speed up knowledge diffusion is via information spillovers (David and Olsen 1992). Such spillovers might benefit both parties in the exchange, since they contribute to the growth in the overall pool of knowledge available for use.

In the specific case of universities, it has also been argued that the gains to be derived from IPR protection should induce universities to produce knowledge that is more relevant to the needs of businesses and of the economy at large, which would in turn facilitate development and commercial exploitation on the part of firms, including academic start-ups (Eisenberg 1996; Berman 2008), and thus foster firms' innovation processes[2].

Consequently, these arguments point to a role of IPRs in enhancing bi-directional flows of knowledge between university and industry: knowledge is transferred more effectively from university to industry, while, at the same time, the knowledge spillovers produced by the IPR exchange and the greater ability of firms to build upon academic knowledge contribute to the creation of a broader pool of knowledge from which universities themselves may benefit.

[2] One of the main objectives of the Bayh-Dole Act was in fact to promote the use of academic research results on the part of small firms (Schacht 2005).

IPRs are assumed to enhance the awareness of existing knowledge in the economic system:

Patents, and copyright when filed, provide immediate information to others who can incorporate such information into their own knowledge bases, even though they cannot make direct commercial use of it. The rationale is that patents are necessary as incentives to induce inventors to disclose their new knowledge instead of keeping it secret. Granting exclusive rights to inventors for their innovations in terms of efficient IPR protection can be viewed as a contract that the inventor gets from government if he or she agrees to disclose the idea in question (the argument is reviewed in Andersen 2004). Therefore, embedding research outcomes into IPRs should help firms gain greater awareness of the knowledge produced by universities (Verspagen 2006), and to gain indirect economic advantages from this information (for example, ideas for the further development of their own research processes).

IPRs are assumed to stimulate flows of economic resources between economic agents:

In the case of universities, the commercialization of discoveries is supposed to help them ensure additional income, an issue that has acquired increasing importance in parallel with the reductions in budgets for higher education.

The main objective of the present empirical analysis (sections 3 and 4) is to assess the validity of this framework with respect to the circulation of knowledge from industry to the academic system[3]. If the assumptions that underpin the Bayh-Dole Act and the subsequent wave of legislation inspired by it hold, we should observe: first, that markets for IPRs (such as patents and copyright markets) better enhance the flows of knowledge from industry to the academic system, when compared with the exchange of IP that is not protected through such instruments (such as open source licenses, confidentiality agreements or no protection); and second, that such markets are efficient, or that, at the very least, they are plagued by less problems than the exchange of forms of knowledge that is not embedded in IPRs. Special emphasis will be given to how IP enhance the universities' own knowledge creation processes.

Therefore, the research questions (RQs) that drive the analysis are the following:

RQ1: Is the exchange of IPRs between university and industry better able to enhance knowledge circulation (and particularly to stimulate the universities' own knowledge creation processes) when compared to the exchange of other forms of non-proprietary IP?

RQ2: Do markets for IPRs work better, or more smoothly, for value creation compared to market exchanges of non-proprietary IP?

2.2. Empirical controversies on the role of academic IPRs for knowledge circulation

In parallel with the growing emphasis placed on the patenting of academic discoveries (on the part of policymakers and academic institutions themselves), numerous critical voices have joined the debate. Critics have begun to worry about the actual and

[3] Elsewhere we have looked at the extent to which evidence supports the claim that IPRs play a role in enhancing knowledge transfer from academia to industry (Andersen and Rossi, 2010a) and in enhancing the flow of economic resources from industry to academia (Andersen and Rossi, 2010b).

potential adverse effects of the enforcement of IPRs on academic knowledge, suggesting that such enforcement may negatively affect the flows of knowledge and financial resources that it is supposed to enhance. Not only the implications but also the actual success of the Bayh-Dole Act and of similar legislation have been questioned.

It has been argued that, while in a short-term perspective the implementation of IPRs on scientific knowledge may seem to stimulate the circulation of knowledge in the economic system, the adoption of a long-term, dynamic perspective reveals that such approach may actually lead to opposite outcomes. We organize this brief review of the literature critical of academic patenting around the main claims upon which Bayh-Dole and similar legislation are based: (i) that IPRs enhance knowledge transfer from academia to industry and (ii) from industry to academia, (iii) that IPRs enhance awareness of research produced in universities, and (iv) that IPRs increase the universities' ability to derive income from their research activities.

In relation to claim (i), some critics have suggested that IPRs may hamper rather than enhance knowledge transfer from academia to industry. It has been argued that the possibility to commercialize the results of research and to reap economic rewards from this activity would induce universities to excessively shift the balance of their knowledge production activities towards applied research, at the expense of their traditional missions of performing basic research and providing education and training. A shift towards applied research would undermine the economic rationale for the public funding of university research in the first place (Nelson 1959). In a dynamic perspective, it is feared that greater orientation towards research with practical implications may lead to a decline in patent quality, in the substitution of patents for publications and in the decline of publications' quality (for a comprehensive review of the debate on the negative effects of university patenting, see Baldini 2008). Over the long term, some commentators worry that encouraging universities to divert financial resources from the pursuit of blue-skies basic research in favour of more applied research may even contribute to slowing down the rate of innovation of the economy (Florida 1999). In fact, not only this would reduce the beneficial knowledge spillovers that basic research generates, but the fact that universities may end up being in direct competition with industrial research may discourage businesses from investing in their own research activities.

These criticisms have been mitigated by empirical research that has shown that increased patenting of research outcomes has not led to a quantitative or qualitative decline in the amount of knowledge transfer activities performed by universities. Some studies have claimed that patenting and publication activities are complementary, with highly productive star scientists reaching high levels of both (Zucker and Darby 1996); others have showed a positive relationship between intellectual eminence and success in research commercialization (Elfenbein 2007); and some have argued that universities have not significantly changed their mix of basic and applied research activities (Rafferty 2008).

Contrary to claim (ii) above (that IPRs enhance knowledge transfer from industry to academia), it has been argued that IPRs can adversely affect the ability of universities to build upon knowledge generated elsewhere, referring to the knowledge feedback that universities derive from industry and from other partners. While in the theoretical and empirical literature on the effects of patenting on innovation processes, universities have mostly been analyzed as institutional knowledge providers,

disseminating their discoveries and transferring technology to industry and the community (Brenznitz, O'shea and Allen 2008), it must be remembered that universities are as much producers of new knowledge as they are users of existing knowledge, both scientific and technological. It is well known that science often builds upon technology: not only because scientists need appropriate technological instruments in order to carry out their investigations (Rosenberg 1994; MacKenzie and Wajcman 1999), but also because technological progress indicates which directions of scientific research yield the highest potential payoffs (Rosenberg 1982; Stokes 1997). Moreover, new discoveries are built upon wider and wider knowledge bases, and therefore the importance of combining external sources of knowledge in order to innovate has increased over time (Chesbrough 2003). This has been documented in studies of industrial dynamics, where it has been shown that inventions increasingly happen along cumulative, path-dependent and complex trajectories (Merges and Nelson 1990; Andersen 2001; Antonelli and Calderini 2008).

Mowery et al. (2001) have argued that the increased privatization of research results may raise the cost of using scientific knowledge and restrict its dissemination, especially as universities increasingly turn to the patenting of more basic discoveries. It has been noted that patenting has enforced some restrictions on disclosures, on data sharing and on the use of previously widely available research tools (Blumenthal et al. 1986; National Research Council 1997) and that these restrictions, in turn, have led to less diversity in experimentation on the part of scientists (Murray et al. 2009), suggesting that disclosure through IPRs may hamper universities' access to knowledge. It has also been suggested that these restrictions reduce awareness of the research carried out by universities - contrary to claim (iii) - since they may lead to less communication between industry and university, delays to industry innovation, loss of proprietary information, and generate obstacles to the emergence of new research fields (for a discussion, see Baldini 2008).

Mitigating evidence suggests that high patenting is mainly confined to a few disciplinary fields (Henderson, Jaffe and Trajtenberg 1998; Geuna and Nesta 2006), and that most knowledge dissemination between academia and industry still takes place through the traditional, non-protected "open science" channels (Meyer-Kramer and Smooch 1998). It has been argued that the increase in patenting activities undertaken by universities since the early 1980s has owed more to the emergence of scientific fields that have many potential commercial applications, such as biotechnology and ICT, than to the effect of legislative changes in themselves (Mowery et al. 2001).

Finally, in relation to claim (iv) that IPRs increase the ability to derive income from their research activities, the effectiveness of academic patenting in enhancing the flows of economic resources to universities has been called into question. It has been shown that income from technology transfer is very skewed, with few universities making money from patents and licences (Charles and Conway 2001; Bulut and Moschini 2006), the direct costs of patenting usually exceed revenues (Charles and Conway 2001) and many university technology transfer offices struggle to be profitable (Kenney 1986). D'Este and Perkmann (2007) have found that, for universities in the UK, collaborative research projects and consultancies are a more important source of income than licensing. According to Macdonald (2009) one of the key problems that may explain the lack of success of many universities in exploiting the patent system for economic reward is that, while the model of knowledge production and transfer based on intensive patenting works well in the pharmaceutical

sector, it is not prevalent in many other industries, where most firms rely upon trade secrets, marketing strategy and lead times to exploit technological advantage (Klevorick et al. 1987). Universities produce a wide variety of research output, but paradoxically they have all adopted a model of technology transfer that is typical of one of the heaviest users of the patent system, the pharmaceutical industry (Arundel and Kabla 1998). This model leads university managers to overvalue university patents (Rappert, Webster and Charles 1999), although in most technologies and for most firms patents are of little value.

The present investigation intends to contribute to the debate on the appropriateness and relevance of protecting academic discoveries through IPRs, with respect to the ability of universities to stimulate their own knowledge creation processes, e.g. by learning or obtaining knowledge from external sources. We will explore, first, the extent to which universities use IPRs in order to enhance their own knowledge creation processes, and, second, whether universities support the assumption that markets for IPRs enhance knowledge flows, compared to non-proprietary forms of IP. If the assumptions that underpin the Bayh-Dole Act and the subsequent wave of legislation inspired by it hold, we should observe, first, that markets for IPRs (such as patents and copyright) better enhance the flows of knowledge from industry to the academic system (thus promoting academic knowledge creation processes), when compared with the exchange of IP that is not protected through such instruments. Secondly, we should observe that such markets are efficient, or that, at the very least, they are plagued by less problems than the exchange of other forms of non-proprietary knowledge. The research design in this paper is original in many respects, thus allowing us to provide an innovative empirical perspective to these issues.

3. Data and research design

The empirical analysis is based upon UKNOW survey data[4] on a sample of universities, university colleges and public research organizations based in England, Scotland, Wales or Northern Ireland, collected between October 2008 and March 2009. The list of relevant organizations was drawn from the website of the University Companies Association (UNICO), which represents the technology exploitation companies of UK universities. From UNICO's website, the list of 120 members was downloaded (updated as of October 2008). This list was then integrated with the set of institutions that responded to the HEBCI 2004-05 and 2005-06 surveys (HEFCE, 2007), which includes 162 universities, university colleges and public research organizations. The two lists were merged and, after correcting different spellings and eliminating double entries, a final population of 169 different organizations was assembled. The survey was administered between October 2008 and April 2009, and we obtained 46 valid responses (27.2% response rate).

The UKNOW 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

[4] 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).

experience of the obstacles encountered when attempting to exchange such IP efficiently, and they have some knowledge of the relative strategic advantages of the different forms of IP as a consequence of the interactions with the researchers themselves.

First, a key contribution of the empirical analysis is to build a more reliable picture of the ways in which universities actually exchange IP, by focusing not only on the exchange of patented academic knowledge, but on a broader range of types of IP, to which so far the economic literature has paid little attention. Universities produce a large variety of research outputs, not all of which is suitable to be patented. Baghurst and Pollard (2009) point out that universities produce, among others: non-software copyrighted materials (articles, reports, books, lecture notes, presentations); software (source level code as well as executable programmes developed by researchers in the course of their research work); materials (synthesised by researchers working in the fields of chemistry and materials); database rights; cell lines; new plant or animal varieties; registered and unregistered designs; photographs and videos; research questionnaires; tacit knowledge (know-how), a class of IP which is difficult to codify and transfer but which is nonetheless valuable to third parties.

Despite the quantitative importance of these forms of IP for universities, the issues relating to its generation, identification and commercial exploitation are under-explored, particularly when contrasted with patents. 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 trademarks, design registrations, copyright (Graham and Somaya 2006; Ramello and Silva 2006) and neglect most other forms of IP. 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). In addition, with some exceptions, most of the literature that focuses on the use of different IP protection mechanisms assumes that they are substitutes rather than complements, despite the lack of evidence in this respect (Nelson 2006; Teece 2006).

By focusing on data collected for four broad forms of IP – patents, copyright, open source and non-patented innovations – the present empirical analysis captures most of the various forms of IP that universities produce. Usually, it is assumed that non-patented IP is transferred to industry as part of a university's normal research and teaching activities (Sorensen and Chambers 2008). Instead, the UKNOW survey explicitly asked universities about the transfer of non-patented IP through several specific governance forms: releasing non-patented innovations to private firms (e.g. consultancy or like) or to the public, using non-patented innovations, and collaborating with other universities without patent restrictions. The following Table 1 lists the different forms of IP and the specific governance structures that have been investigated through the UKNOW survey.

Table 1. Forms of IP and governance structures 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 innovations to the public Releasing not patented innovations to private firms Using not patented innovations Collaborating with universities without patent restrictions

Universities were asked about their stock of patents owned and licensed, whether they engaged in each patent governance form, and if so their number of transactions in the last two years. With respect to open source, non-patented innovations 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.

Second, the survey allows us to investigate the relative importance that universities attribute to a set of strategic benefits that the literature has identified as crucial reasons to trade patents. That is, we explore whether universities' answers are consistent with the view that the exchange of patents is more effective than the exchange of other forms of IP in order to reach specific benefits related to several types of knowledge and resource flows (cfr. Figure 1).

The universities that took part in the survey were asked to indicate what strategic benefits they derive when exchanging different forms of IP through each of the possible governance forms listed in Table 1. Table 2 below lists the 13 options that universities were presented with, from which they were asked to select up to 5 most important ones. Particularly, we investigate how universities strategically use IP in order to derive knowledge feedbacks from industry, and thus enhance their own knowledge creation processes. An objective here is to assess whether universities consider this benefit more important when exchanging patents than when exchanging other forms of IP.

Table 2. Benefits investigated through the survey

Type of flow	*Specific benefit variables*
(i) Knowledge transfer	• Building informal relationships with industry networks • Increasing ability to enter collaborative agreements • Giving something to the community
(ii) Knowledge creation	• 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
(iii) Awareness of research base	• Increasing market share; • Professional recognition or brand recognition; • Competitive signalling
(iv) Financial resources	• Direct income from market transactions • Cost cutting • Increasing ability to raise venture capital

Another key assumption underlying Bayh-Dole-inspired legislation is that IPR markets function well. However, in an institutional economics perspective, all markets are institutions characterized by specific norms and bargaining forms, where, for trade to take place, social relations need to be underpinned by trust and similar expectations (in relation to prices, contracts and other aspects) between buyer and seller (Hodgson 1988, 1999). According to this approach, IP markets cannot be reduced to simple price-clearing mechanisms representable through supply and demand curves; rather, they are platforms of social relations in which value is created. We use the notion of "marketplace" (rather than "market") to denote the space, actual or metaphorical, in which exchange transactions take place, and to emphasize the web of social relationship and institutions that support such transactions. This view opens up the possibility that IP marketplaces may not function as smoothly as assumed when they are conceptualized as simple price-clearing mechanisms.

Several problems with the functioning of IP marketplaces have been identified by the empirical literature, usually relating to patents and other proprietary IP. These 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, Schwartz and Wagner 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. 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; see Bessen and Meurer 2005), 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).

By investigating the obstacles that university encounter when they exchange IP (particularly when they seek to enhance their knowledge creation processes), we check whether universities agree that IPR markets function efficiently, as the theory predicts.

In the survey, universities were asked to select, from a list of 14 possible choices (listed in Table 3), up to five most serious obstacles encountered when exchanging each form of IP, through each governance form.

Table 3. Obstacles to IP exchange investigated through the UKNOW survey

Type of obstacle	*Specific obstacle variables*
(i) Search problems	• Difficulty in locating the owners of IP • Difficulty in locating the users of IP • Difficulty in finding the best IP
(ii) 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
(iii) Contract negotiation	• Difficulty in negotiating a price for the IP • Difficulty in negotiating the terms, not related to price, of the contract
(iv) 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)
(v) Regulation and practices	• Different practices of firms • Regulations allow too exclusive rights • International IP regulations do not fit the needs of different local markets

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[5].

4. Analysis

4.1. IP marketplaces and universities' contribution to knowledge circulation in the economy

The sample includes organizations that belong to several institutional types. Most are universities, some are university colleges and other higher education colleges (such as music conservatoires and arts colleges), and a few are public research organizations. Table 4 compares the distribution of institutions in the sample and in the sets of respondents, across several main characteristics: geographic localization, size (in terms of total staff employed, academic, non-academic and atypical), 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

[5] 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 HE-BCI survey (relative to 2007).

they were founded[6]). The distribution of respondents is representative of the overall sample.

Table 4. Structure of sample and respondents

		sample (169)	*respondents (46)*
		%	%
geographic localization	England	82.2	89.1
	Wales	5.3	4.3
	Scotland	11.2	6.5
	Northern Ireland	1.2	0.0
	total	*100.0*	*100.0*
type	"old" universities	5.9	8.7
	"red brick" universities	17.8	26.1
	"plate-glass" universities	13.6	15.2
	"former polytechnics"	20.7	19.6
	"modern" universities	16.6	8.7
	colleges of higher education	16.6	8.7
	public research organizations	7.7	13.0
	other	1.2	0.0
	total	*100.0*	*100.0*
size (total staff)	<500	10.7	4.3
	500-1000	13.0	10.9
	1000-5000	47.3	56.5
	>5000	24.3	28.3
	missing	4.7	0.0
	total	*100.0*	*100.0*

We first explore the extent to which universities exchange different forms of IP, and the strategic benefits that they seek from each of these exchanges, in order to confront the first research question (RQ1): is the exchange of IPRs between university and industry better able to enhance knowledge circulation - and particularly to stimulate the universities' own knowledge creation processes - when compared to the exchange of other forms of non-proprietary IP?

Of the 46 respondents, 13 do not exchange any of the four forms of IP. Of the respondents that exchange IP, only 10 (30%) exchange only one type of IP, while most (23, that is 70%) exchange two or more types (9 exchange two different types of IP, 10 exchange three, and 4 exchange all four types). In particular, 9 organizations (27%) only exchange proprietary IP (patents and/or copyright), two organizations (6%) only exchange non-proprietary IP (open source and/or non-patented innovations) while most exchange a combination of proprietary and non-proprietary forms of IP (22 organizations, or 67%). This seems to indicate that, for most universities, exchanging both proprietary and non-proprietary IP represent complementary rather than alternative strategies of knowledge acquisition and transfer.

Table 5 details the shares of different types of organizations that engage in the exchange of patents, copyright, open source and non-patented innovations (shares

[6] 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").

greater than 40% are highlighted in bold). The rows do not sum to 100% since each organization can participate in more than one marketplace.

Table 5. Participation in IP marketplaces by type of organization

		all	*Patents*	*copyright*	*non-patented innovations*	*open source*
		N	%	%	%	%
type	"old" universities	4	**75**	**75**	**50**	**50**
	"red brick" universities	12	**50**	17	33	25
	"plate-glass" universities	7	**57**	**43**	29	14
	"former polytechnics"	9	**89**	**44**	**44**	33
	"modern" universities	4	25	0	25	25
	colleges of higher education	4	25	25	0	**50**
	public research organizations	6	**100**	**83**	33	0
size (all staff)	less than 500	2	**50**	**50**	0	**50**
	500-1000	4	**50**	25	0	0
	1000-5000	24	**63**	38	33	25
	more than 5000	16	**69**	**44**	**44**	31

Public research organizations, old universities founded before the XIX century and former polytechnics that have become universities in 1992, are the institutions that engage the most in exchanging patents. Old universities and former polytechnics are also most active in the exchange of non-patented innovations and of other forms of IP, suggesting, once again, that proprietary and non-proprietary IP seem complementary rather than substitute. If we focus on the three types institutions which are most active within each IP market place we see that old universities and former polytechnics are the most "commercial universities" in terms of using IP marketplaces.

With respect to size in terms of staff (including academic, non-academic, atypical), the data suggest that the share of organizations that engage in open source is higher for the smaller size categories (less than 1000 staff) and lower for larger size categories, while the share of those that engage in patents is larger in the latter. Larger organizations report higher shares of engagement in all forms of IP (except for open source), suggesting that they produce a greater variety of research outcomes and possibly that they are better able to sustain the transaction costs involved in engaging in different IP marketplaces[7].

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). The total stock of in-licensed patents is a small fraction (about 7%) of the total stock of owned patents, suggesting that universities tend to file their own patents rather than in-license them from other organizations. On average, the number of patent transactions in the previous two years equals 25% of the universities' total portfolio of owned patents. Universities have been particularly active in out-licensing patents (on average, each university out-licensed 11 patents in the previous two years), in selling patents (3.6 transactions on average) and in cross-licensing them (3.5 transactions on average). Of the 15 universities that exchange formally registered

[7] This is consistent with the results of a Poisson regression on the number of IP marketplaces that universities engage in (considering the subset of 33 universities that engage in at least one marketplace), which has been found to be positively and significantly influenced by the size of the organization in terms of total staff.

copyright, many are active in selling it (9) and out-licensing it (12), while fewer universities buy (3) and/or in-license (3) copyright. These results are in line with the conventional view of universities as knowledge producers, more active in developing knowledge and transferring it to other organizations (embedded in IPRs) rather than in acquiring it from the outside.

Instead, when universities exchange non-proprietary IP, they tend to be active in a variety of governance forms at the same time. Of the 18 organizations that exchange non-patented innovations, most release non-patented innovations to the public (15) or to private firms (12), use non-patented innovations (16) and collaborate with other universities without patent restrictions (15). The average numbers of transactions in the previous two years are also quite high: each university engaged on average in 11.3 transactions involving the release of non-patented innovations to the public, in 23.3 transactions involving the release of non-patented innovations to private firms, in 12.5 transactions involving the use of non-patented innovations, and in 25 collaborations with other universities. All of the 12 universities 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. In the previous two years, universities participated, on average, in 2.3 open source software projects.

Summing up, data on the exchange of the various types of IP suggest that universities that exchange proprietary IP mainly do so in order to transfer knowledge to external agents (selling and out-licensing patents and copyright) while they trade non-proprietary IP both in order to transfer knowledge to external agents and to acquire knowledge from the outside (open source engagement, releasing non-patented innovations, using non-patented innovations, collaborating with other universities). This suggests that when universities seek to acquire knowledge from external sources, they do not preferentially rely on patents and copyright.

We further investigate this issue by considering the universities' responses with respect to the strategic benefits they seek when exchanging different forms of IP. In Table 6 below, responses are aggregated at the level of marketplaces. Shares do not sum to 100%, since respondents could choose benefits in more than one category. Shares greater than 40% are highlighted in bold.

Table 6. Benefits from participation in IP marketplaces: overview

	patents	*Copyright*	*non-patented innovations*	*open source*
respondents in each IP marketplace	29	15	18	12
types of benefits:	%	%	%	%
(i) knowledge transfer	**66**	**67**	**72**	**83**
(ii) knowledge creation	31	**47**	**61**	**58**
(iii) awareness	28	**67**	**44**	17
(iv) financial	**66**	**67**	**50**	0

Table 6 shows that universities transfer knowledge to industry and other partners by exchanging all forms of IP, and particularly non-proprietary IP. Financial benefits are particularly sought from exchanging patents and copyright, while benefits relating to increased awareness of the university's research base are particularly important when exchanging copyright and non-patented innovations. Benefits relating to knowledge creation are particularly sought when universities exchange non-proprietary IP - open source and non-patented innovations. That is, in order to foster their own knowledge

creation processes, universities prefer to rely on freely disseminated knowledge rather than on protected knowledge. The result that universities particularly seek to transfer and/or acquire knowledge by exchanging non-proprietary IP counters some of the rationales supporting the increased patenting of academic research (see literature reviews in sections 1 and 2).

4.2 IP governance and knowledge creation in universities

Further insight can be derived by investigating the specific benefits related to knowledge creation that universities seek from each IP governance form. Table 7 shows, for each form of IP, the share of respondents that selected each specific type of benefit related to knowledge creation, with respect to the set of respondents that selected knowledge creation benefits overall (shares greater than 40% are highlighted in bold).

Then, for each governance form 'j', Table 7 shows the "revealed advantage" of that governance form when seeking a particular knowledge creation benefit 'i'. The index in each cell is the share of universities that seek a particular knowledge creation benefit 'i' when engaging in a particular governance form 'j', relative to the overall importance of that particular benefit (measured as the share of universities across all governance forms which seek that particular knowledge creation benefit)[8]. In other words, let x_{ij} be the number of times that knowledge creation benefit 'i' is chosen in governance form 'j', then the revealed governance advantage RGA index (as explained above) is:

$$RGA = (x_{ij}/\sum_i x_{ij})/(\sum_j x_{ij}/\sum_i\sum_j x_{ij})$$

The index is measured across all governance forms within each IP marketplace. An index is greater that one (highlighted in bold) means that a governance form has a relative advantage in terms of conferring a specific knowledge creation benefit.

For the subset of universities that use patents for knowledge creation purposes, the most important benefits involve developing better technology (accomplished particularly by selling and out-licensing patents) and involving users or suppliers as a development strategy (accomplished particularly by out-licensing, pooling and in-licensing patents). This may indicate that patenting induces universities to produce knowledge that is more directly applied to commercial needs, or that the commercial sector require patent protection in collaborative research or like. Using or developing compatible products or creative expressions is the main benefit universities seek from copyright, particularly when purchasing, selling and in-licensing it. Only very few organizations exchange patents or copyright in order to use the best innovations available.

[8] The Revealed Governance Advantage (RGA) can be compared to the Revealed Technological Advantages (RTA) index (first used in patent statistics by Keith Pavitt and John Cantwell) and the Revealed Comparative Advantage (RCA) index, which is an index (first used in international economics by Bela Balassa) for calculating the relative advantage or disadvantage of a certain country in a certain class of goods or services as evidenced by trade flows. The Revealed Market Advantage (RMA) developed in later sub-section is a similar type of relative index.

Table 7. Knowledge creation benefits sought, by specific IP type, in each IP governance form (includes revealed governance advantage (RGA) indexes)

	Specific knowledge creation benefits				
forms of IP and governance forms:	*number of respondents that selected knowledge feedback benefits*	*innovation methodology/ developing better technology*	*benefiting from user or supplier involvement as a development strategy*	*being able to use the best inventions or innovations*	*setting common standards / making or using compatible technology*
Patents	9	**67%**	**44%**	22%	0%
• selling	3	**1.91**	0.00	0.00	-
• out-licensing	8	**1.19**	**1.13**	0.00	-
• cross-licensing	3	0.95	0.75	**1.75**	-
• pooling	1	0.00	**3.00**	0.00	-
• buying	0	-	-	-	-
• in-licensing	4	0.38	**1.20**	**2.80**	-
Copyright	7	14%	29%	14%	**71%**
• selling	2	0.00	0.00	0.00	**1.50**
• out-licensing	5	**1.71**	**1.71**	**1.71**	0.64
• buying	2	0.00	0.00	0.00	**1.50**
• in licensing	1	0.00	0.00	0.00	**1.50**
non-patented innovations	11	**91%**	27%	36%	27%
• releasing to the public	7	**1.05**	0.50	0.78	**1.75**
• releasing to private firms	7	**1.17**	**1.33**	0.52	0.78
• collaborating with universities	6	0.81	**1.38**	**1.44**	0.54
• using	5	**1.05**	0.75	**1.17**	0.88
open source	7	**71%**	**57%**	**57%**	**43%**
• software	7	0.91	**1.14**	0.86	**1.14**
• pharmaceutical	1	**3.20**	0.00	0.00	0.00
• other communities	1	0.00	0.00	**4.00**	0.00

All kinds of knowledge creation benefits (see Table 7) are very important to universities that engage in open source: universities do so in order to develop better technology, to learn from users or suppliers, and, to a lesser extent, to use the best inventions and to set common standards (but the benefits are somehow different according to the field in which the open source project is carried out). The most important knowledge creation benefit sought from the exchange of non-patented innovations is the possibility to develop better technology (particularly when using non-patented innovations and when releasing them to public or to private firms). Being able to use the best inventions is an important motivation for over a third of respondents that exchange non-patented IP for knowledge creation purposes, particularly when using non-patented IP and when collaborating with other universities.

Table 9 shows, for universities of different historical origins and of different sizes, the revealed IP marketplace advantage (RMA) - that is the advantage of each IP

marketplace in conferring benefits relating to knowledge creation[9]. The index in each cell is, for universities of type (or size) 'k', the relative advantage of marketplace 'j' in conferring knowledge creation benefit 'i': that is, the importance of benefit 'i' sought in marketplace 'j', relative to the importance of benefit 'i' in all IP marketplaces. If x_{ij} is the number of times that benefit 'i' is sought in marketplace 'j', then the RMA index for universities of type or size k (RMA_k) is defined as follows:

$$RMA_k = (x_{ij}/\sum_i x_{ij})/(\sum_j x_{ij}/\sum_i\sum_j x_{ij})$$

When the index is greater that one, that type of IP has a relative advantage in terms of conferring knowledge creation benefit 'i' for universities of that particular type or size. The index is computed for universities of all types and size categories.

Table 9.Relative market advantage (RMA) indexes explaining the relative advantage of each type of IP marketplace in conferring benefits relating to knowledge creation

	Categories 'k'	*Patents*	*Copyright*	*Non-patented innovation*	*Open source*
type	"old" universities	0.00	0.00	0.00	**4.00**
	"red brick" universities	0.84	**1.05**	**1.05**	**1.40**
	"plate-glass" universities	0.00	0.83	**1.25**	**2.50**
	"former polytechnics"	0.65	**1.04**	**1.07**	**1.56**
	"modern" universities	-	1.00	-	-
	colleges of higher education/university colleges	0.00	-	**4.00**	1.00
	public research organizations	0.95	0.00	**1.33**	-
size	less than 500	0.92	-	0.92	**1.22**
	500-1000	1.00	-	1.00	-
	1000-5000	0.43	**1.09**	**1.45**	**1.64**
	more than 5000	0.77	0.80	0.91	**1.70**

Given our previous section 4.1 illustrated how universities mostly use non-proprietary for enhance their knowledge creation processes our RMA results are not surprising. We find that patents are never considered to have a relative advantage in providing knowledge creation benefits, compared to other forms of IP, by universities of any type and size. Conversely, for universities of most types and most sizes it is open source and/or non-patented innovations that have a relative advantage in terms of providing knowledge creation benefits (in some cases it has not been possible to compute the index, when universities of a particular type or size did not engage at all in a certain marketplace).

These results indicate that universities appear to be very driven to use and produce knowledge that can be freely diffused and built upon, as could be expected from public institutions whose main mission is still the production of knowledge as a public good. Thus, our empirical evidence does not support the claim that formal IPRs better enhance the circulation of knowledge between academia and external commercial partners, with respect to the feedback flows of knowledge from industry to academia. Rather, universities reveal that non-proprietary IP strategies are preferable.

[9] When aggregating the four knowledge creation benefits into one single variable, care has been taken in eliminating double counting of universities' responses.

4.3. The effectiveness of IP marketplaces for academic knowledge creation

The last part of our analysis concerns the perceived efficiency of IPR marketplaces with respect to marketplaces for other IP. We confront the second research question (RQ2): do markets for IPRs function more smoothly, compared to market exchanges of non-proprietary IP?

For each of the universities that report benefits related to knowledge creation, we analyze what kind of obstacles they identify as being most important. Table 10 summarizes the main obstacles encountered by those universities that report the use of IP for knowledge creation benefits. The shares are computed by aggregating responses at the level of marketplaces[10] (shares greater than 40% are highlighted in bold).

We find that universities experience numerous obstacles in all IP marketplaces, and that the exchange of proprietary IP is not less affected by problems than the exchange of non-proprietary IP. Rather, the shares of universities that report each type of problems appears to be slightly higher in the case of proprietary IP than in the case of non-proprietary IP.

Table 10. Obstacles to participation in IP marketplaces on the part of universities that seek knowledge creation benefits

	patents	*copyright*	*non-patented innovations*	*open source*
respondents that selected innovation benefits	9	7	11	7
types of obstacles	%	%	%	%
Search	**78**	29	**46**	**57**
Transparency	**100**	**100**	**64**	**57**
contract negotiation	**100**	**86**	**55**	14
contract enforcement	**44**	**57**	27	**57**
regulation and practices	11	**43**	9	14

If we consider the specific obstacles within each category (listed in Table 3), we find that, in the patent marketplace, universities that seek knowledge creation benefits encounter search problems (difficulty in finding the best patents and difficulty in finding the potential users of patents are each reported by 44%), low transparency (problems in assessing the degree of novelty and the economic value of the patent are reported by, respectively, 67% and 89%), contract negotiation issues (problems in negotiating price and non-price terms of the patent contract are reported by, respectively, 56% and 78%).

In the copyright marketplace, lack of transparency is the main problem, particularly the lack of clarity of the copyright document and the difficulty in assessing the degree of novelty of copyright (each reported by 86% of respondents that seek innovation benefits from copyright). This makes it difficult to negotiate the copyright price (problem reported by 43%). Also, 43% of respondents claim that they find it difficult to identify the best copyright. Interestingly, these problems are not due to insufficient or too strict regulation (no respondents have reported regulation obstacles in the case of copyright, and only 22% complain that international patent regulations do not fit the needs of different local markets), suggesting that improving the functioning of IPR marketplaces is not simply an issue of defining clear rules and making sure that

[10] When aggregating the 14 IP market obstacles into five broader variables, care has been taken in eliminating double counting of universities responses.

they are enforced. Rather, the problems are often related to the nature of the protected knowledge, so that potential buyers and sellers find it difficult to assess its economic value, and hence to negotiate its price (a problem reported by 56% in the case of patents and 43% in the case of copyright) and other terms of the IPR contract (reported by 78% in the case of patents).

Search, transparency and contract negotiation problems are also present in the case of non-patented innovations. 46% of respondents that exchange non-patented innovations for knowledge creation purposes find it difficult to assess their economic value, and 55% find it difficult to negotiate a price. 36% find it difficult to locate the potential users of non-patented innovations – a relatively high share, but lower than in the case of patents. This indicates that owners of patented IP do not necessarily find it easier to find a "demand" for it than owners of non-patented IP.

Universities that engage in open source software development for knowledge creation purposes mainly experience obstacles relating to lack of transparency (difficulty in assessing the economic value of open source, a problem reported by 43%), search problems (difficulty in finding the best technology available, a problem reported by 43%) and contract enforcement issues connected with lack of trust in the other party's willingness to comply with the open source rules (a problem for 29% of respondents). That is, participants in open source projects are often worried that their counterpart will behave opportunistically, free riding on the common development effort in order to develop their own protected IP.

In sum, universities see IP marketplaces, including patent and copyright marketplaces, as far from working smoothly. While in the theoretical mainstream literature IPR exchange is often assumed to be perfectly transparent and characterized by a perfect flow of information, in practice universities find that this is not the case.

5. Conclusion

While most analyses on 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 presented here suggests that universities acquire and transfer knowledge using several forms of IP (patens, copyright, open source and IP with no formal protection). These are more often used in a complementary rather than alternative way, especially on the part of larger institutions, which are better able to sustain the transaction costs involved in engaging in different IP marketplaces. Universities that are larger in terms of total staff tend to engage in a larger variety of IP marketplaces, and are particularly active in patents, while smaller organizations tend to focus on fewer IP marketplaces, and are particularly active in open source.

Institutional characteristics also seem to matter, with old universities (which are particularly research-oriented) and former polytechnics (which are particularly engaged in commercial relationships with industry) being the most likely to exchange a broad range of IP. Therefore, better understanding of how knowledge flows between university and other economic agents, such as industry and government organizations, requires that researchers, managers and policy makers focus on a broader range of IP types than just patents.

We find that universities use all forms of IP intensively in order to transfer their knowledge to industry or government. However, they prefer to rely on non-proprietary IP governance forms characterized by open access and lack of proprietary enforcement (i.e. open source and no-patent strategies) when aiming to enhance their own knowledge creation processes through their commercial services.

In this context, universities participate in most non-proprietary IP governance forms in particular in order to use and "develop better technology" themselves and to "use the best inventions or innovations". These findings counter the arguments, at the basis of Bayh-Dole and similar legislation, which claim that the implementation of IPR enhances the circulation of knowledge between university and the commercial sector, and particularly the feedback flows of knowledge from industry to academia.

More research into these issues would be useful in order to shed further light on the domain of application of different forms of IP, and to explore in particular whether the exchange of different types of IP reflects the exchange of intrinsically different "knowledge products" or whether it reflects the universities' strategic choice to specifically trade protected vs. open access knowledge. From our data, it appears that different forms of IP (patents, copyright, open source and no-protection), and even specific governance forms for the exchange of IP (such a different licensing forms etc.), reflect explicit value-seeking behaviour on the part of universities. This is because they are associated to different strategic benefits related to knowledge creation (innovation methodology, user-supplier involvement, access to "best" inventions/innovations, and standard setting). Thus, while the fact that universities transfer only a small part of their discoveries via patent selling and patent licensing is often attributed to their lack of awareness and to their inability to use these instruments, our results suggest that alternative channels for the transfer of IP are used deliberately by universities because they confer certain advantages to a greater extents than exchanging patents.

Finally, universities that are exchanging IP in order to enhance their own knowledge creation processes encounter many different obstacles. Rather than insufficient or excessive regulation, these obstacles especially concern the nature of academic knowledge, whose economic value is difficult to assess, and this in turn generates difficulties in the negotiation of contracts. These problems are particularly relevant both in the cases of patents and non-patented innovations. Evidence from our survey therefore does not support the claim that more intensive patenting of knowledge produced by universities leads to more efficient and smoother transactions with external agents. Rather, it highlights the difficulties in assessing the value of knowledge that has potentially broad applications, but that may be at an early stage of development. There are also issues having to do with lack of transparency in all IP marketplaces inhibiting or reducing the value creation process from IP - especially in relation to difficulties in finding the relevant IP or the relevant agents owning/holding or demanding the IP. Removing these obstacles would require specific interventions fine-tuning the institutions that underpin transactions in the different IP marketplaces and introducing ways to promote information diffusion.

References

Andersen, Birgitte. 2001. *Technological Change and the Evolution of Corporate Innovation: The Structure of Patenting 1890–1990*. Cheltenham: Edward Elgar.

Andersen, Birgitte. 2004. If intellectual property rights is the answer, what is the question? *Economics of Innovation and New Technology*, 13(5): 417–442.

Andersen, Birgitte and Federica Rossi. 2010a. Beyond Bayh-Dole: universities and the use of proprietary and non-proprietary intellectual property marketplaces. DIME-IPR Working Paper Series n. 90.

Andersen, Birgitte and Federica Rossi. 2010b. Intellectual Property governance and the pursuit of economic rewards in UK Universities. *Strategic Change: Briefing in Entrepreneurial Finance*. 19: 243–264.

Antonelli, Cristiano. 2005. Models of knowledge and systems of governance. *Journal of Institutional Economics*. 1(01): 51-73.

Antonelli, Cristiano and Mario Calderini. 2008. The governance of knowledge compositeness and technological performance: the case of the automotive industry in Europe. *Economics of Innovation and New Technology*. 17(1):23-41

Arora, Ashish, Fosfuri, Andrea and Alfonso Gambardella. 2001. *Markets for Technology: Economics of Innovation and Corporate Strategy*. Cambridge, MA: MIT Press.

Arrow, Kenneth. 1962. Economic welfare and the allocation of resources for invention. In *The Rate and Direction of Inventive Activity* ed. Richard Nelson, 609-25. Princeton, NJ: Princeton University Press.

Arrow, Kenneth. 1974. *The limits of organization*. New York: W.W. Norton.

Arundel, Anthony and Isabelle Kabla. 1998. What percentage of innovations are patented? Empirical estimates for European firms. *Research Policy.* 27: 127–141.

Association of University Technology Managers (AUTM), 2002. AUTM U.S. Licensing Survey, FY 2000. Northbrook, IL: AUTM.

Baghurst, David and Terry Pollard. 2009. *A Literature Review on the Efficiency and Effectiveness of University Intellectual Property. Models for the Generation, Identification and Exploitation of "Soft" (Non-Patent and Non-Trademark) IP*, SABIP Report.

Baldini, Nicola. 2008. Negative effects of university patenting: Myths and grounded evidence. *Scientometrics*. 75(2): 289–311.

Berman, Elizabeth. 2008. Why did universities start patenting? Institution-building and the road to the Bayh-Dole Act. *Social Studies of Science.* 38: 835–871.

Bessen, James and Michael Meurer. 2005. The patent litigation explosion. Working Papers 0501, Research on Innovation.

Blumenthal, David, Gluck, Michael, Karen Seashore Louis, Stoto, Michael and David Wise. 1986. University-industry research relationships in biotechnology: implications for the university. *Science*. 232(4756): 1361-1366.

Breznitz, Shiri, O'Shea Rory P. and Thomas J. Allen. 2008. University commercialization strategies in the development of regional bioclusters. *Journal of Product Innovation Management*. 25(2):129-142.

Bulut, Harun and GianCarlo Moschini. 2006. US universities' net returns from patenting and licensing: a quantile regression analysis. Working Paper 06-WP432, Center for Agricultural and Rural Development, Iowa State University.

Campbell-Kelly, Martin and Daniel Garcia-Swartz. 2008. Pragmatism not ideology: IBM's love affair with open source software. Available at SSRN: http://ssrn.com/abstract=1081613

Charles, David and Cheryl Conway. 2001. *Higher education – Business interaction survey*, Higher Education Funding Council for England, London.

Chesbrough, Henry W. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Crespi, Gustavo, Geuna, Aldo and Bart Verspagen. 2006. University IPRs and knowledge transfer. Is the IPR ownership model more efficient? SPRU Electronic Working Paper Series 154.

Dasgupta, Partha and Paul A. David, P.A. 1994. Toward a new economics of science. *Research Policy*. 23: 487-521.

David, Paul A. and Trond E. Olsen. 1992. Technology adoption, learning spillovers, and the optimal duration of patent-based monopolies, *International Journal of Industrial Organization*, 10, pp. 517–543.

D'Este, Pablo and Marcus Perkmann. 2007. Why do academics collaborate with industry? A study of the relationship between motivations and channels of interaction. Paper presented at the DRUID Summer Conference, Copenhagen, 18-20 June.

DTI. 1993. *Realising Our Potential: A Strategy for Science, Engineering and Technology*. London: HMSO.

Eisenberg, Rebecca S., 1996. Public research and private development: patents and technology transfer in government-sponsored research. *Virginia Law Review*. 82: 1663–1727.

Elfenbein, Daniel W. 2007. Publications, patents, and the market for university inventions. *Journal of Economic Behavior & Organization*. 63: 688–715.

Feldman, Maryann and Ian Stewart, I. 2006. *Knowledge Transfer and Innovation: A Review of the Policy Relevant Literature*. Report Prepared for the Ontario Ministry of Research and Innovation.

Feller, Irving. 1990. Universities as engines of R&D based economic growth - they think they can. *Research Policy*. 19: 335-348.

Florida, Richard. 1999. The role of the university: leveraging talent, not technology. *Issues in Science and Technology*. 15(4): 67-73.

Geuna, Aldo and Alessandro Muscio. 2008. The governance of university knowledge transfer. SEWPS Working Paper 173.

Geuna, Aldo and Lionel J. Nesta. 2006. University patenting and its effects on academic research: the emerging European evidence. *Research Policy*. 35: 790–807.

Graham, Stuart J.H. and Deepak Somaya. 2006. Vermeers and Rembrandts in the same attic: complementarity between copyright and trademark leveraging strategies in software. Georgia Institute of Technology TIGER Working Paper.

Hall, Bronwyn H. and Rosemarie Ziedonis. 2001. The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995. *RAND Journal of Economics*. 32(1): 101-28.

HEFCE. 2007. *Higher education-business and community interaction survey*. Report, July 2007/17.

Henderson, Rebecca, Jaffe, Adam B. and Manuel Trajtenberg. 1998. Universities as a source of commercial technology: a detailed analysis of university patenting 1965–1988. *Review of Economics and Statistics*. 80(1): 119–127.

Hodgson, Geoffrey. 1988. *Economics and Institutions: A Manifesto for a Modern Institutional Economics*. Oxford: Polity Press.

Hodgson, Geoffrey. 1999. *Economics and Utopia: Why the Learning Economy is not the End of History*. Economics as Social Theory series. London and New York: Routledge.

IBM. 2006. Building a New IP Marketplace: A Global Innovation Outlook 2.0, Innovation Outlook Report, IP marketplace

Kenney, Martin. 1986. *Biotechnology: The University Industrial Complex*. New Haven, CT: Yale University Press.

Klevorick, Alvin, Levin, Richard, Nelson, Richard R., Winter, Sidney, Gilbert, Richard and Zvi Griliches. 1987. Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity*. 3.

Lawton Smith, Helen. 2007. Universities, innovation and territorial development: A review of the evidence. *Environment and Planning C: Government and Policy*. 25(1): 98–114.

Lucas, Robert. 1988. On the mechanics of economic development. *Journal of Monetary Economics*. 22:3-42

Macdonald, Stuart. 2009. *Seducing the goose: patenting by UK universities*. University of Sheffield, mimeo.

Mackenzie, Donald and Jane Wajcman. 1999. *The Social Shaping of Technology*. Milton Keynes: Open University Press.

Mansfield, Edwin, Schwartz, Mark and Samuel Wagner. 1981. Imitation costs and patents: an empirical study. *Economic Journal*. 91:907-918

Merges, Robert and Richard Nelson. 1990. On the complex economics of patent scope. *Columbia Law Review*. 90(1): 839-961.

Meyer-Krahmer, Frieder and Ulrich Schmoch. 1998. Science-based technologies: university–industry interactions in four fields. *Research Policy*. 27: 835–852.

Montagnani, Lucia. 2009. Open source software, patents and royalty-free licensing. Paper prepared for the 4th Annual Conference of the EPIP Association – 24-25 September 2009.

Mowery, David C. 1983. Economic theory and government technology policy. *Policy Science*. 16.

Mowery, David, Richard R. Nelson, Bhaven N. Sampat and Arvidis Ziedonis. 2001. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole Act of 1980. *Research Policy.* 30: 99-119.

Mowery, David C. and Bhaven N. Sampat. 2005. Bayh-Dole Act of 1980 and university-industry technology transfer: a model for other OECD governments? *Journal of Technology Transfer*. 20(1-2): 1115-127.

Murray, Fiona, Aghion, Philippe, Dewatripont, Mathias, Kolev, Julian and Scott Stern. 2009. Of mice and academics: examining the effect of openness on innovation. NBER Working Paper No. w14819.

National Research Council, 1997. *Intellectual Property Rights and Research Tools in Molecular Biology*. Washington. D.C.: National Academy Press.

Nelson, Richard R. 1959. The simple economics of basic scientific research. *The Journal of Political Economy*. 67(3): 297-306.

Nelson, Richard R.. 2006. Reflections of David Teece's Profiting from technological innovation. *Research Policy*. 35(8): 1107-1109.

Quah, Dan. 1998. A weightless economy. *UNESCO Courier*. December: 18-21.

Rafferty, Matthew. 2008. The Bayh–Dole Act and university research and development. *Research Policy*. 37(1): 29-40.

Ramello, Giovanni B. and Francesco Silva. 2006. Appropriating signs and meaning: the elusive economics of trademark. *Industrial and Corporate Change*. 15(6): 937-963.

Rappert, Brian, Webster, Andrew and David Charles. 1999. Making sense of diversity and reluctance: Academic-industrial relations and intellectual property. *Research Policy*. 28: 873-90.

Rivera-Batiz, Luis A. and Paul Romer. 1991. Economic integration and endogenous growth. *The Quarterly Journal of Economics*, vol. 35, no. 4: 971-1001.

Romer, Paul. 1990. Endogenous technological change. *Journal of Political Economy*. 98, no. 5: S71-S102.

Rosenberg, Nathan. 1982. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press.

Rosenberg, Nathan. 1994. *Exploring the Black Box*. Cambridge: Cambridge University Press.

Schacht, Wendy. 2005. *The Bayh-Dole Act: Selected Issues in Patent Policy and the Commercialization of Technology*. CRS Report for US Congress.

Sorensen, J. and Chambers, D. 2008 Evaluating academic technology transfer performance by how well access to knowledge is facilitated-defining an access metric, *Journal of Technology Transfer*, 33, 534-547.

Stokes, Donald E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington. D.C.: Brookings Institution Press.

Tang, Puay 2008. *Exploiting University Intellectual Property in the UK*. London: Intellectual Property Institute.

Teece. David J. 2006. Reflections on profiting from innovation. *Research Policy*. 35(8): 1131-1146.

Verspagen, Bart. 2006 University research, intellectual property rights and European innovation systems. Journal of Economic Surveys. 20: 607-632.

Zucker, Lynne G. and Michael R. Darby. 1996. Star scientists and institutional transformations: patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences*. 93(23): 12709–12716.