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ACADEMIC INVENTIONS OUTSIDE THE UNIVERSITY: A RESULT OF INDUSTRY SPONSORSHIP OR ENTREPRENEURIAL ACTIVITIES?

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Academic inventions outside the university: A result of industry sponsorship or entrepreneurial activities?*

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Abstract

This paper investigates the link between firms and academic inventors on firm-assigned academic patents for a sample of UK academics. The first descriptive results show that 43% of firm assigned patents are in fact owned by a university spin-off. The empirical analysis finds that a strong appropriation regime at a university encourages patents owned by the university or its spin-offs. Public research funds and technology transfer grants are also associated with university or spin-off owned patents. Government incentives and funding regulations thus are a successful strategy to encourage and maintain university ownership of patents. Industry sponsorship on the other hand encourages firm ownership of patents, whether these are private firms or university spin-offs. A more detailed analysis of funding links shows that 41% of non-spin-off firms also have funding agreements with the university; however, the remaining 59% of firms have no apparent link to researchers that could explain ownership of university inventions.

Keywords: Academic patenting; University-industry collaboration; Sponsored research; Academic entrepreneurship; Patent ownership

JEL codes: I23; 031; 034

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1 Introduction

Previous work has shown that in Europe a large proportion of patented inventions by academic researchers are not owned by the university but by private firms (Geuna and Nesta, 2006; Lissoni et al., 2008). This may be due to appropriation norms that have allowed researchers or funding agents to maintain the rights to their inventions or due to universities' difficulties in handling intellectual property rights. Changes in legislation and the continuing efforts of universities have led to a more rigid IPR regime for academic staff. However, even now the majority of university inventions are not assigned to the academic's institution. Lissoni et al. (2008) find that in some countries in Europe up to 80% of academic inventions are assigned to a firm. For the UK, Sterzi (2012) reports that a 50% share is owned by companies. This share is much larger than comparable numbers for the US, where only 24% of academic patents are assigned solely to firms (Thursby et al., 2009) and points towards a very different development in Europe.

The appropriation of academic IP has been encouraged by policy makers to foster technology transfer from universities to industry and to enable the commercialisation of academic research. The objective behind the increased incentives for academic researchers to appropriate their research results is the prospective additional income it may provide to universities (DTI, 2006; DIUS, 2008). Further, university ownership is promoted as it is in a position to potentially increase the efficiency of technology transfer by allowing non-exclusive licenses, enabling a wider use of an invention, and by allowing for a better search strategy that ensures the commercialisation of the invention and thus providing wider socio-economic benefits (see Crespi et al. (2010) for a review).

However, if the majority of university inventions are not owned by universities, as is the case in Europe, then these objectives cannot be met. Several papers have further shown that firm-assigned academic patents are less basic than university-owned ones and are therefore more likely to produce immediate income to applicant firms (Crespi et al., 2010; Czarnitzki et al., 2011; Thursby et al., 2009). Patents left with the university are those in need of more investment and little to no immediate returns that could benefit the plunging budgets of universities. In terms of economic costs for the university, industry ownership implies that the returns to academic research and public research investments would go to a private firm and may thus present a problem of lost potential returns on public research investment to universities and lost knowledge transfer opportunities.

Still, most of the literature on the topic has ignored the fact that a large share of assignee firms are in fact university start-ups, often at least partially owned by the university. Thursby et al. (2009) have shown that 32% of firm owned patents are start-up patents and that these inventions receive more forward citations than university owned academic patents. Firm ownership may thus simply indicate a different appropriation strategy of the university (Markman et al., 2008). It has further been hypothesised that firm assignees are sponsors of academic research (Thursby et al., 2009; Verspagen, 2006) and there has indeed been some evidence for a positive effect of industry sponsorship on academic patents (Hottenrott and Thorwarth, 2009; Hottenrott and Lawson, 2012; Lawson, 2012). However, there is no research linking sponsoring firms directly to specific patents. Further, while there have been some attempts to explain industry vs. university ownership of patents, different types of industry ownership have yet to be explored. This paper therefore aims to find ex-ante predictors for the industry ownership of patents and to identify the types of firms that own academic patents and their links to academic inventors.

It investigates empirically if we can observe patent ownership ex-ante, i.e. before the patent is filed, and predicts future patent ownership by looking at appropriation strategies of universities and private and public funding. The paper uses data from a sample of engineering academics at 13 UK universities that were employed at these universities for all the years 2001 through to 2007. The data includes all patents assigned to these researchers between 2001 and 2008 as well as all funding received from industry between 2001 and 2007. The first descriptive results show that 43% of firm assigned patents are in fact owned by a university spin-off. The empirical analysis finds that a strong appropriation regime at a university encourages patents owned by the university or its spin-offs. Public research funds and technology transfer grants are also associated with university or spin-off owned patents. Government incentives and funding regulations are therefore a successful strategy to encourage and maintain university ownership of patents. Industry sponsorship on the other hand encourages firm ownership of patents, whether these are private firms or university spin-offs. A more detailed analysis of funding links shows that 41% of non-spin-off firms also have funding agreements with the university; however, the remaining 59% of firms have no apparent link to researchers that could explain ownership of university inventions.

In the remainder of this paper we summarise some existing literature on university-industry collaboration and academic patenting, describe the data, give some descriptive statistics and introduce the empirical framework. We then present preliminary results and finally conclude.

2 Academic Patenting and Ownership

Firm-university links have been studied intensively in the past decade and most empirical papers report a multitude of channels through which universities and industry engage in collaborative work (e.g. Agrawal and Henderson, 2002; Cohen et al., 2002). Literature on firm-university links identifies several characteristics of the firm that affect its propensity to engage with universities, and found size to be an important predictor. It finds that large firms and start-ups have closer links to academia and are also more likely to benefit from academic research (Cohen et al., 2002; Mohnen and Hoareau, 2003; Fontana et al., 2006). Additionally, R&D intensive firms have a higher capacity for engaging in collaborative research, perhaps through jointly financed projects or contract research. However, very few papers investigate the reasons for firm ownership of academic patents or directly address the role of grants for different firm ownership regimes. Three explanations for why university-invented patents are assigned to private firms have been brought forward and are discussed in this section: industry research sponsorship, spin-off activity and consulting or unregistered activities.

2.1 Industry Sponsorship

Firm innovation literature has stated that R&D intensive firms are not only more likely to collaborate with universities but that these collaborations may result in a higher innovative output (George et al., 2002; Liebeskind et al., 1996). The university and the sponsoring firm may agree that any IP resulting from such joint research projects are assigned to both the university and the firm or solely to the firm (Thursby et al., 2009; Verspagen, 2006). However, knowledge of such collaboration agreements is limited and there has been little evidence confirming the link between sponsorship and patent ownership. Several papers have shown that collaboration with industry and other applied sponsors may help overcome the barrier between scientific and commercial activities and that contact with pro-commercialisation sponsors positively affects a researcher's attitude towards patenting as well as her ability to recognise commercial opportunities (Lawson, 2012; Owen-Smith and Powell, 2001; Stuart and Ding, 2006). Indeed, Colyvas and Powell (2006), looking at technology transfer activities at Stanford University, observe that TTOs and researchers see industry sponsors as potential partners for patenting activities, i.e. licensing. Asking firms for benefits derived from collaboration with university researchers, Lee (2000) finds that 53% of firms realised substantial or considerate benefits in developing new patents. Also 29% of academic researchers in Lee's sample reported that the joint research led to patentable

outcomes or, for 19% to new business opportunities. A positive link between patenting and industry collaboration has already been confirmed in several survey studies. Gulbrandsen and Smeby (2005), in a survey of Norwegian academics, find a strong positive correlation between patenting and industry collaboration and funding. Also, Hottenrott and Thorwarth (2011) show that the share of funding coming from industry positively affects the number of patents in a sample of German professors. Lawson (2012) confirms a positive effect of industry sponsored research on patenting propensity for a panel of UK researchers; however, the paper did not find a stronger effect for industry owned patents. This may be due to considering patents owned by university spin-offs as industry owned patents. Thus, accounting for the nature of the patenting firm may be of relevance when investigating the effect of industry sponsorship.

2.2 University Start-Ups

Further many privately owned patents are, in fact, assigned to university start-ups in which the university holds a share. The new company facilitates the commercialisation of the new invention and enables the acquisition of additional funding for commercialisation. Several papers have investigated university spin-off formation and its role for technology transfer (e.g. Di Gregorio and Shane, 2003; Clarysse et al., 2011; Fini et al., 2011; Lockett and Wright, 2005; Stuart and Ding, 2006). Inventions that result in such start-ups are less basic and may create immediate financial returns as described in Czarnitzky el al. (2011), and Thursby et al. (2009) making it more attractive for a researcher or the university to set up a new firm. While firms that constitute university spin-offs are relatively easy to identify, only Thursby et al. (2009) have provided some statistics on the extent of university patents owned by university start-ups. They report that 32% of all firm owned patents in the US are owned by such university spin-offs and that these are of higher quality than patents owned by industry or private firms. They assume, however, that such start-up activities are initiated by the academics, concluding that it presents a way to bypass university administration. Instead, start-ups could represent a deliberate commercialisation strategy of the university (Markman et al., 2008). Particularly in the UK, spin-off formation has been a preferred commercialisation strategy for universities. Even though US universities are more successful in licensing, UK universities create many more spin-off companies (HEFCE, 2011) and many of its university start-ups have become successful global companies. Markman et al. (2008) indeed found some evidence that researchers at universities with a higher number of start-up

companies are more likely to file a patent that is owned by a firm or an individual. We can thus expect that universities with an entrepreneurial commercialisation strategy, i.e. with a larger number of spin-offs, are more likely to file patents owned by spin-offs.

2.3 Consulting Contacts

Thursby et al. (2009) assume that firm-owned patents could arise as a result of consulting activities or a result of researcher's 'bypassing' university administration to draw direct benefits from their inventions. Consulting is little researched but may hold an explanation for why academics appear as inventors on industry owned patents. Since in most countries academics are permitted to spend some of their time on consulting, these arrangements would not be regarded as time spent in their job and thus any inventions resulting from these activities would not belong to the university (Thursby et al, 2009). Consulting is more difficult to measure but may hold an explanation when no formal link between firms and researchers can be found. Lawson (2012) looks at the effect of small grants aimed at dissemination activities and finds a positive effect on patenting. These small grants may be indicative of close links between the sponsor and the researcher and provide a proxy for consulting. Further, researchers bypassing their employers and offering their inventions directly to a firm may be included in the consulting argument brought forward by Thursby et al. (2009) which gives no conclusive picture on whether it regards these activities as part of the academic job or illegal external engagements.

3 Data

3.1 Data Collection

To investigate the link between industry-sponsored research and firm-assigned academic patents, we collected data on commercial and funding histories of 744 tenured engineering academics that were employed at thirteen UK universities during the period 2001 to 2007. Initially, all engineering academics were identified using staff registers in academic calendars and on university websites[1]. This provided the basis for collecting researchers' patent histories from existing databases. Thirteen universities additionally provided information on external funding received from industry, government and public bodies for the period 2001 to 2007. The number of academics employed at these thirteen institutions between 2001 and 2007 is 744. Personal information could be collected for 687 researchers.

[1] For a detailed description of the data see Banal-Estanol et al. (2010).

Patents

For each academic in the dataset, patent applications stating her as an inventor and filed between 2001 and 2008 were collected from esp@cenet, developed by the European Patent Office (EPO). The web interface allows searches for patent applications filed with the EPO but also those filed with the UK Intellectual Property Office (UKIPO) or the US patent office (USPTO) and other national patent offices. We consider here all patent applications that state the researcher as an inventor and hence not only applications filed by the university but also those assigned to third parties, including industry. Data construction required a manual search in the inventor's database to identify those entries where the identity of the academic was certain. This was done by comparing addresses, titles and technology classes for all patents potentially attributable to each researcher. As each invention can lead to multiple patent applications (e.g. at different patent offices), we additionally verified each entry with the Derwent World Patents Index (DWPI) that contains information grouped around a base patent application, thus enabling me to uniquely identify the original invention and avoid multiple counts. Of the 744 researchers in our database, 176 file at least one patent application during the period 2001 to 2008. Thus, approximately 23% of researchers in engineering filed at least one patent during the eight year observation period. The number of base patent applications filed by these 176 researchers is 467. Additionally, we identified the applicant on each patent and differed between patents assigned to a firm and those assigned to others. We consider all applications associated to one base patent to find the assignee, as ownership can change across time and with different patent offices. If a patent, or one of its sister patents, has more than one assignee they are all are considered. In this sample 249 patent applications are assigned to a private firm, and 97 researchers have at least one such firm-assigned patent between 2001 and 2008. Thus 53% of patents are at least co-assigned to a company, a share similar to the one found by Sterzi (2012).

Firm-assigned academic patents

The 249 firm-assigned academic base patents are associated to 115 different companies. We collected information for each of these companies from public registers and recorded their size in terms of numbers of employees. Table 1 reports the number of companies by size. Of the 115 companies that filed patents with academic inventors between 2001 and 2008, 54 are large firms with more than 250 employees and 33 are micro-entities with fewer than 10

employees[2]. Only 28 companies are small or medium-sized enterprises (10-249). 43% of firm-assigned academic patents (108 patents) are owned by large multinational firms with more than 250 employees, 89 patents are assigned to small and medium-sized enterprises (SMEs) and 61 patents to micro-entities. Note that patents can be assigned to more than one company and that therefore the number of patents does not add up to 249. In this sample 8 patents have more than one company applicant (see Table 1).

Previous papers have found that a large share of firm-assigned academic patents may be owned by university start-ups. We therefore identify those companies that were spun out from universities. This was done by consulting company registers and browsing the websites of universities for lists of start-ups. In this sample, 32 companies are university spin-offs. Table 1 shows their size in terms of number of employees. Most university spin-offs are micro-entities. More interestingly, while only about 28% of all firm applicants are university spin-offs, they account for 43% of all firm-assigned patents (106 patents). Thus, a large share of academic patents owned by industry is in fact owned by a company with a university professor as its principal. This share is even higher than the one found by Thursby et al. (2009) for US patents. However, the distribution of patents across spin-off companies is highly skewed. While 17 spin-off companies have filed only one patent application during the observation period, just 4 spin-off companies account for 50% of all spin-off patents.[3] Overall the descriptive analysis shows that the majority of firms that filed academic patents are large multinational firms or university spin-offs. This is in line with previous literature that showed that large firms and start-ups are more likely to engage in and benefit from collaborations with universities (Cohen et al., 2002; Mohnen and Hoareau, 2003; Fontana et al., 2006).

External Funding

Funding information for each academic was provided by the research offices of the thirteen universities. They include names of principal investigators (PIs), funding periods, funding amounts and the exact names of sponsoring agents. Funding from industry accounts for 20%

[2] We follow the parameters suggested by the European Commission (2003) to define company size in terms of number of employees.

[3] Of the 106 patents, 37 are owned by just two Cambridge University spin-offs.

of total external funding[4] and 454 researchers are a PI on at least one grant during 2001 and 2007, while 279 held at least one industry-sponsored grant. These industry sponsored grants may hold the explanation for firm ownership of patents.

In addition to industry grants we consider two other types of funding sources, public grants and technology transfer grants. Public grants, which include research council funding but also funding from charities which contribute significantly to research in the UK, represent 60% of total external funding. Public grants are usually aimed at basic research and if they facilitate new inventions require researchers to file patents with the university. Technology transfer grants are government-funded schemes and regional development programmes to support and fund knowledge transfer to the economy. The most prominent form of government support was the Teaching Company Scheme (TCS) set up in 1975 (and replaced by the Knowledge Transfer Partnership (KTP) in 2003) to facilitate so called 'business-knowledge base' collaboration, for economic benefit and to train young professionals. TCS/KTP specifically focuses on SMEs which in 2006 were involved in 80% of the programmes (DTI 2002, TSB 2007). The programmes have been found to contribute to a company's success and organisational change (DTI 2002, TSB 2007, Senker and Senker 1995). A second focus of government-sponsored collaboration is on initiatives of regional and economic development agencies (e.g. Yorkshire Forward, Scottish Enterprise) that promote knowledge transfer specifically for the economic benefit of the region. In Scotland and Wales these agencies were established between 1965 and 1976 and in England following the RDA Act 1998 and are funded by their respective government departments. They specifically assist local SMEs in identifying university partners and have initiated science parks and enterprise hubs to help foster collaboration. RDAs moreover provide initial funding for academic spinoffs and commercialisation of university inventions. Overall most central and local government initiatives focus on providing access to academic consultancy for SMEs and support to commercialise university inventions. These grants are non-research grants and thus only account for 2% of researcher's income. However, they may help to explain patent ownership as they specifically support university ownership of patents and spin-offs.

Other Characteristics

[4] Total funding also includes EU grants and funding from government ministries. As the aim of these types of funding is more difficult to evaluate and we have no hypotheses about their impact they are omitted from the analysis.

For 687 academics we were able to collect personal information, including gender, year of PhD and PhD subject area. In this sample of engineering academics, 7% are women. The average year of PhD award is 1984, with the earliest PhD year being 1958. 55 researchers do not hold a PhD. The share of women and the average year of PhD are the same for the 176 academic inventors, suggesting that there is no gender or age bias amongst academic inventors.

The majority of engineering academics holds a PhD in an engineering subject: 21% in electrical and electronic engineering and 19.5% in civil engineering, while 15% did their PhD in physics, 14% in chemical engineering, and 13% in mechanical engineering. A smaller share of researchers holds a PhD in life sciences.

This distribution is very different when we look at the subject areas of researchers that are inventors on at least one patent between 2001 and 2008. While academics in electrical and electronic engineering only account for 21% of academics, they account for 34% of academic inventors. Accordingly, the share of academic inventors amongst electronics' staff is 34.7%. Also, 30% of engineering staff with a PhD in physics filed a patent between 2001 and 2008. The share is still above average for researchers with a background in chemical engineering or life-sciences. There are fewer inventors amongst researchers in civil or mechanical engineering, disciplines that may be more likely to produce designs rather than patents. The distribution of academics with at least one firm-assigned invention across scientific fields is similar to that of all academic inventors. Academic inventors in civil and mechanical engineering seem to be more likely to file patents with industry, indicating that the few inventors in these two fields may have been spurred by industry towards patenting their research. The number of firm-assigned patents per academic again differs between fields. Academics with a background in electrical and electronics engineering as well as physics publish more patents than their peers in other disciplines.

3.2 Empirical Strategy

The empirical set-up is organised in two steps, firstly, the paper investigates when an invention by an academic researcher is filed with a firm or the university as opposed to other types of ownership; and secondly, it explores the relationship between different ownership regimes, the university, its spin-off and or an established firm. We hypothesized that ownership is determined by the appropriation strategy of the university which may favour university ownership of patents or spin-off activities. Further, ownership is determined by the

funding agent, with industry funding supporting ownership by established firms and technology transfer grants supporting university or spin-off ownership. Finally, we test whether research sponsored through public grants and resulting in top publications is less likely to result in firm patents. We include several personal characteristics as controls

Each observation is a patent filing event, thus, we can have more than one observation per researcher and even multiple observation per year if a researcher patented more than once in a given year. We therefore cluster standard errors at the individual level. If a patent has more than one inventor who is an academic in our dataset, we consider the more senior inventor.[5] Only patents filed between 2004 and 2008 are considered to be able to build reliable measures of all explanatory variables. Personal characteristics are observed in the year of filing. Institutional characteristics are observed in the year before filing. As for project characteristics, we observe funding and publications from 2001 to 2007 and expect their stock in previous years to reflect a researcher's current research profile and thus to affect patents immediately. In other words, we predict the ownership of a patent filed in 2004 with publications and funding between 2001 and 2003 and the ownership of patents filed in 2008 with publications and funding during the whole period 2001 to 2007. Summary statistics of all variables used in the regression are presented in Table 2. The number of patents in the empirical analysis is reduced to 251 due to missing values in some of the estimators and a reduced observation period of 2004 to 2008. 39% of patents are owned by the university and 58% by firms, 46% of which are university start-ups. The remaining 3% are owned by individuals or government.

3.3 Variables

Funding

Researchers receive grants from a variety of sponsors but we only consider funding from industry, from public bodies (research councils and charities) and funding from local governments that are directly aimed at supporting regional knowledge transfer. Other types of funding (i.e. from EU and government ministries) are not considered in this analysis as the nature of these grants cannot easily be inferred. Funding variables represent the stock of funding received since 2001. The amount of industry funding (*INDFUND*) and its share on the total external budget (*INDSHARE*) received by a researcher since 2001 should inform us of her involvement in industry led research. We further differ between large research grants

[5] Only two patents have more than one inventor in the dataset.

of 50000 GBP or more (INDFUND_RES) and small consulting grants of less than 50000 GBP (INDFUND_SMALL). Small grants are not directed towards research and may be indicative of close relationships between an academic and a sponsor and thus better explain firm owned patents than research grants. The total amount (*PUBFUND*) and share (*PUBSHARE*) of public research grants since 2001 on the other hand will act as a proxy for basic research involvement. We also include the amount (*TTFUND*) and share (*TTSHARE*) of technology transfer grants to the regression.

Institutional characteristics

To measure the appropriation strategy of the university, we use information from the Higher Education and Business and Community Interaction (HE-BCI) Survey that surveys universities about their external business related activities. The survey has been running since 2003 and provides detailed information on the university level about spin-off and patenting activities. To measure the entrepreneurial culture of a university, we use the number of active[6] formal start-ups (*SPINTOT*) in year *t-1*. To measure the culture of appropriation, we use the university's cumulative patent portfolio in *t-1* (*UNIPATSTOCK*). In the regressions logs of both measures are used to normalise their distribution.

It would be more convincing to also control for university fixed effects, but there is not sufficient variation over time in the spin-off and patent stock variables to include a university control. The two appropriation strategy variables, however, should capture any university specific effect that influences patent ownership, though one cannot rule out some remaining unobserved heterogeneity.

Publications and Patent History

Additionally, research characteristics are measured through the publication activity of researchers. Publications were collected from the Web of Science for the years 2001 to 2007 and we consider the yearly average of publications (*AVGPUB*) up to *t-1*. The number of publications is regarded a proxy for the scientific value of the project.

I also include the yearly average of patents filed between 2001 and *t-1* to capture any potential learning effects of the researcher (*AVGPAT*).

Personal characteristics

[6] The survey reports the number of still active, surviving start-ups owned by the university.

I include the age at the time of invention as measured in terms of years since PhD (*AGE*) and gender (*FEMALE*) to control for personal characteristics. Additionally, we consider the seniority of the researcher through a dummy that takes the value one if she is a professor (*PROFESSOR*). To control for scientific field we include a dummy for researchers with a PhD in physics or electrical and electronic engineering (*ELEC*) as this category differed from other fields in the descriptive analysis. A dummy stating whether the researcher has a PhD (*NOPHD*) is included in all regressions (not reported) as age and scientific field are only available for PhDs.

4 Results

4.1 Firm vs University Ownership

I firstly estimate a bivariate probit model to measure the probability that a researcher will publish a patent with a firm as opposed to other regimes or file an invention with the university as opposed to other regimes. The probability that researcher i will choose appropriation method k, is the probability that y_{ik} is larger than all other y_{ij}. As a researcher has the choice between two or more outcomes, their standard errors are not independent and therefore require me to estimate them simultaneously. A patent can further be assigned to both the university and the firm or to neither, making it necessary to consider a bivariate model as opposed to a binary choice model.

Results are reported in Table 3. Columns 1, 3 and 5 report results for industry owned patents and columns 2, 4 and 6 results for university owned patents in three different model specifications. The results show that an increase in industry funding increases the probability to file a patent with industry, and it reduces the probability to file a patent with the university. The share of funding received from industry shows the same signs. The higher the share of funding received from industry the higher the propensity that a patent is owned by a firm and the lower the propensity that it will be owned by the university. Thus, industry sponsored researchers are indeed more likely to file their patents with a firm partner. If we differ between small and large grants coming from industry we see that both have a positive effect on firm ownership but that the effect is significant only for small consulting grants. These small grants also negatively affect the propensity of university ownership. The amount of public funding is not significant for either type of ownership regime, however, a larger share of funding received from public, no strings attached, funding agents, increases the probability of filing a patent with the university and decreases the probability of firm assignment.

Technology transfer grants have a positive effect on university ownership, and negatively affect industry ownership.

The stock of publications has a negative effect on firm ownership and a positive, albeit insignificant effect in the university ownership equation. Previous patents have a positive effect on industry ownership.

The measures for institutional characteristics show that researchers at universities with more spin-offs are more likely to file their patent with a firm and less likely to choose a university ownership regime. Curiously, the number of university owned patents has no significant effect in either specification.

None of the individual characteristics is significant in the regression, indicating that there is no difference in terms of age, rank or gender between academics that patent with the university and those patenting with a firm. Patents owned by researchers in physical sciences and electrical and electronics engineering are perhaps less likely to be owned by a firm although the effect is only significant in column 5.

4.2 Different Strategies, Different Firms

I then estimate a multinomial logit in which we investigate the relationship between assignment of a patent to the university, its spin-off or an established firm. All estimations include year fixed effects and are clustered at the individual level. Results are reported in Table 4 and presented as relative risk ratios (RRR). The number of observations is reduced to 231 as all patents owned by individuals or the government are excluded. The first column presents the comparison of spin-off patents with university assigned patents. The results show that industry sponsorship increases the risk of a spin-off assigned patent relative to a university assigned patent. Other types of sponsorship have a negative sign but are insignificant. Column four shows that the risk of a patent to be owned by a spin-off is also increased relative to university ownership when the share of funding coming from industry increases. Column seven then confirms that this effect is driven by small consulting grants. The average number of publications and patents does not predict the difference between university and spin-off owned patents. However, the university's appropriation strategy is a direct indicator for ownership. The number of spin-offs owned by the university increases the risk of spin-off ownership relative to university ownership.

Column two reports the relative risk ratios for patents owned by independent companies relative to university owned patents. Again, industry funding increases the risk of firm

ownership, while technology transfer grants and the share of public funding decrease the risk. Once again small industry grants drive the positive effect of industry funding and the coefficient is higher than the one for spin-off patents. Further, average publication numbers are negative and point towards a lower risk for university faculty with a good publication history to file patents outside the university. Previous patens have a positive significant effect, indicating that researchers with a strong patent portfolio are more at risk of filing a patent with a private firm as opposed to leaving the ownership to the university. Also, the appropriation strategy of the university is indicative of ownership. Researchers at universities with a strong spin-off portfolio are more likely to file patents with a firm while researchers at universities with a large patent portfolio are more likely to leave the ownership rights to their institution.

Finally, we compare spin-off patents and those owned by other firms. The results report the risk of filing a spin-off patent relative to leaving a patent to an outside firm. We find no significant difference in funding amounts between the two ownership regimes. However, researchers who receive a larger share of external income from public agents are more likely to patent with a university start-up. Further, we cannot see any significant difference in terms of publication and patent history. In terms of university strategy, researchers at institutions with a large patent portfolio are more at risk of filing a spin-off patent relative to other firm patents, but the spin-off portfolio is insignificant. Thus researchers at universities with a stronger spin-off portfolio do not necessary file more patents with these spin-offs but may benefit from an open appropriation environment that also favours other ownership regimes.

Women are less likely to file patents with a spin-off as opposed to other firms and universities. Other individual factors are not significant.

4.3 Links between Firm Assignees and Academics

The empirical results indicate a close link between industry sponsorship and firm ownership of patents. In the original sample, 97 researchers appeared as inventors on 249 patents assigned to 115 companies of which 32 are university start-ups. Industry links through research funding partnerships on the other hand are far more widespread than industry links through patents (e.g. Agrawal and Henderson, 2002; Cohen et al., 2002). In our sample, 279 researchers received 617 industry grants from 420 different companies. The empirical results suggest that these funding partnerships result in joint patents and we therefore identify all the firms that sponsor researchers in a department and link them to patents produced by a

researcher or her research group[7]. The matching shows that only 31 companies that sponsor research in a university department also appear as an applicant on a patent application by one of its academic staff (see Table 5). Thus, the majority of academics do not take out patents assigned to a sponsoring firm. Amongst the 31 companies that appear as sponsors and as patent applicants, 24 are large multinational companies, 5 are university spin-offs and 2 are other small and medium-sized firms. Collaboration could further be inferred from joint patent applications that state a firm and the university or one of its spin-offs as applicants. In our sample only 13 patents are assigned jointly to a university or its spin-off and a firm. Most of these co-assignees had also already been identified as sponsors of academic research.

Table 5 gives an overview over the different links between academic inventors and the companies that own their patents. We can already conclude that 32 firms stated as applicants on an academic's patent are university spin-offs. A further 26 firms are sponsors of academic research and patents may have resulted from this research. An additional 5 companies are stated as co-assignees on a university owned patent and may therefore be licensees of the invention. However, 51 firms hold patents by academic inventors without having any further visible connection to the researcher.[8] Of the 27 large companies that hold academic patents but do not have a funding agreement with a specific university researcher, 15 are sponsoring research of other inventors but cannot be directly linked to patents in the sample. Also, 15 large companies filed an academic patent before 2004 and the patent may therefore reflect funding placed before 2001. The fact that these companies have a history of involvement with universities and their role as multinationals indicates that they may have sponsored academic research. Perhaps this sponsorship took place before 2001 or was directed to the department as a whole and not to individual researchers. The 12 SMEs that appear as patent assignees but have not sponsored academic research are all located in the UK near universities and are mostly involved in manufacturing or testing. Similarly the majority of the micro-entities are located near universities, though they are a less uniform group with some firms being holding companies that may simply act on commercialisation matters on behalf of researchers or firms, retail companies which, again, may act on behalf of researchers to market their products abroad, small R&D firms and family run manufacturing firms. The

[7] We can only identify the principal investigator on a grant, who may not necessarily be involved in the specific patent, and therefore consider all funding received in the department instead of the funding received by the specific researcher.

[8] The share of unidentified companies drops to 35% if we only consider patents field between 2004 and 2008 and industry grants between 2001 and 2007.

SMEs and micro-entities active in manufacturing and testing may have benefitted from Knowledge Transfer Partnerships or other government initiatives that connect local SMEs with universities. In fact, for 16 companies the inventor is PI on a public or technology transfer grant which may have been responsible for endorsing this patent, though in the empirical section we could not find any evidence that knowledge transfer grants endorse firm patents.

5 Conclusion

The paper investigated the patent ownership of university invented patents. Prior research in the field has shown that academics in Europe are inventors on a large number of patents that are not assigned to the academic's institution but to a private firm or the academic herself (Geuna and Nesta, 2006). This may be due to appropriation norms that have allowed researchers or funding agents to maintain the rights to their inventions or due to universities' difficulties in handling intellectual property rights. Changes in legislation and the continuing efforts of university administrations have led to a more rigid IPR regime for academic staff. However, even now the majority of university inventions are not assigned to the institution. For example, in the UK around 50% of university inventions are filed with a private firm and not the university.

Using data on engineering academics in the UK, this paper investigated the drivers behind university and firm ownership of university invented patents. It differed between patents assigned to university spin-offs and patents assigned to other private firms and used information on university appropriation strategies and industry funding to shed light on the factors that drive firm ownership of patents. The first descriptive results showed that 28% of firms that own university invented patents are university start-ups and account for 43% of firm assigned patents. Thus, a major share of academic patents owned by industry are in fact owned by a university run company[9]. Patents owned by such start-ups have been shown to be of higher value than other university invented patents (Thursby et al., 2009) and start-up formation may thus present an alternative appropriation strategy of the university.

Using bivariate probit and multinomial analysis we saw that researchers at universities with a strong patent portfolio are more likely to file a patent with the university or a university start-up. Thus overall, a strong appropriation regime of the university encourages patents owned

[9] All identified start-ups were originally held by the university but may have been sold or privatised at the time of the patent.

by the university or its spin-offs. Public research grants, as expected, are also associated with university or spin-off owned patents while regional technology transfer grants are primarily associated with university ownership. Thus, government incentives and funding regulations are a successful strategy to encourage and maintain university ownership of patents.

Industry sponsorship and a strong spin-off strategy, on the other hand, encourage firm ownership of patents, whether these are established firms or university spin-offs. This indicates that contact with firms and start-up creation encourages researchers to also pursue the appropriation of academic research. When differing between research grants from industry and small, perhaps consulting, grants, we saw that the effect of industry is primarily driven by small grants that do not support research. These small grants may be indicative of a close link between the sponsor and the researcher and support the idea that firm ownership of academic patents is a result of consulting agreements.

With regard to policy, one could argue that universities forgo IP ownership if they receive research sponsorship. However, in cases where no sponsorship is received, universities lose potential licensing income if a university invented patent is owned by a firm. While the regressions showed a positive link between industry sponsorship and firm ownership of patents, a more detailed analysis revealed that 45% of patenting firms do not have any sponsorship or spin-off links to their academic inventors. Reasons may be found in the placement of sponsorship before the start of the observation period or support through knowledge transfer grants. Further, inventions may rightfully have been sold by the university before their first publication; however, private agreements between firms and researchers could also be responsible for these patents. As already stated in Thursby et al. (2009), these inventions may include IP that should rightfully be owned by the university. It further becomes apparent that the implicit assumption that firms only sponsor academic research if they can retain the ownership over resulting IP is not supported. Only seven per cent of sponsoring firms are applicants on academic patents and sponsoring agreements may instead represent applied work that does not result in new IP.

Finally, while the results allow making inferences about the effect of university IPR regimes and industry sponsorship on patent ownership, the results cannot be interpreted as direct links. Instead, they are indicative of a culture in which the appropriation of knowledge is promoted and rewarded. The paper also shows that more research is needed to better explain ownership regimes, and that more diverse processes may be at work when decisions regarding

appropriation of knowledge are made. Thus, more information on sponsoring firms and projects is needed.

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Tables

Table 1: Firms that apply for patents with at least one university inventor (2001-2008)

Firm Characteristics	# firms	# patents	# university spin-off	# spin-off patents
micro-entity (<10 employees)	33	61	20	42
small or medium-sized firm (<250 employees)	28	87	12	64
large firm	54	109	0	0
Total	115	257	32	106

Table 2: Descriptive statistics of regression variables

	Mean	Sd	Min	max	count
Patent Owner					
University	0.39	0.49	0.0	1	251
Firm	0.58	0.49	0.0	1	251
Spin-Off	0.27	0.44	0.0	1	251
Established firm	0.31	0.46	0.0	1	251
Project characteristics					
INDFUND (in £100000)	3.29	10.02	0.0	61	251
INDFUND_RES (in £100000)	2.97	9.84	0.0	60	251
INDFUND_SMALL (in £100000)	0.33	0.47	0.0	2	251
PUBFUND (in £100000)	4.43	13.19	0.0	129	251
TTFUND (in £100000)	0.26	0.98	0.0	7	251
INDSHARE	4.43	13.19	0.0	129	251
PUBSHARE	0.30	0.35	0.0	1	251
TTSHARE	0.04	0.15	0.0	1	251
AVGPUB	3.60	4.07	0.0	22	251
AVGPAT	0.66	0.91	0.0	4	251
Institutional characteristics					
SPINTOT	23.96	13.65	0.0	46	251
UNIPATSTOCK	159.31	116.61	0.0	441	251
Personal characteristics					
NOPHD	0.05	0.21	0.0	1	251
AGE (years since PhD)	20.37	9.50	0.0	44	251
FEMALE	0.05	0.21	0.0	1	251
PROFESSOR	0.58	0.49	0.0	1	251
ELEC	0.62	0.49	0.0	1	251

Table 3: Bivariate Probit: University Ownership and Firm Ownership (Marginal Effects)

	Model 1		Model 2		Model 3	
VARIABLES	Firm Patent	University Patent	Firm Patent	University Patent	Firm Patent	University Patent
Project characteristics						
INDFUND	0.00960**	-0.0104***				
	(0.00420)	(0.00391)				
INDFUND_RES					0.00457	-0.00514
					(0.00494)	(0.00455)
INDFUND_SMALL					0.228*	-0.237**
					(0.119)	(0.107)
PUBFUND	-0.00210	0.000691			-0.00186	0.000495
	(0.00302)	(0.00301)			(0.00302)	(0.00292)
TTFUND	-0.0534*	0.0682**			-0.0496	0.0648**
	(0.0325)	(0.0295)			(0.0316)	(0.0282)
INDSHARE			0.266**	-0.220*		
			(0.133)	(0.126)		
PUBSHARE			-0.244**	0.213*		
			(0.109)	(0.116)		
TTSHARE			0.0117	0.165		
			(0.262)	(0.267)		
AVGPUB	-0.0302*	0.0232	-0.0209**	0.0122	-0.0249	0.0182
	(0.0177)	(0.0167)	(0.00964)	(0.0100)	(0.0163)	(0.0152)
AVGPAT	0.133***	-0.0506	0.0933*	-0.0160	0.139***	-0.0587
	(0.0443)	(0.0517)	(0.0481)	(0.0569)	(0.0447)	(0.0511)
Institutional Characteristics						
LN(SPINTOT)	0.160***	-0.124**	0.160***	-0.119**	0.160***	-0.122**
	(0.0554)	(0.0583)	(0.0541)	(0.0574)	(0.0547)	(0.0597)
LN(UNIPATSTOCK)	-0.0421	0.0271	-0.0410	0.0236	-0.0551	0.0393
	(0.0434)	(0.0455)	(0.0433)	(0.0458)	(0.0437)	(0.0455)
Individual Characteristics						
AGE	0.0288	-0.0330	0.0319	-0.0370	0.0340	-0.0379
	(0.0229)	(0.0242)	(0.0227)	(0.0244)	(0.0231)	(0.0235)
AGE^2	-0.001	0.001	-0.001	0.001	-0.001	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FEMALE	-0.0231	0.0383	0.0148	0.00147	-0.0526	0.0737
	(0.115)	(0.109)	(0.116)	(0.107)	(0.120)	(0.104)
PROFESSOR	0.0442	0.112	0.0439	0.120	-0.0104	0.160
	(0.110)	(0.107)	(0.104)	(0.105)	(0.112)	(0.0985)
ELEC	-0.116	0.0767	-0.0930	0.0534	-0.133*	0.0959
	(0.0855)	(0.0877)	(0.0833)	(0.0869)	(0.0791)	(0.0809)
University Dummies	No	No	No	No	No	No
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Rho	-0.962***		-0.961***		-0.960***	
Observations	251		251		251	
Cluster	111		111		111	
log Likelihood	-228.9		-226.2		-224.5	

Robust standard errors in brackets, clustered at the individual level. Marginal effects are reported.

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Multinomial Logit: University Ownership and Firm Ownership (RRR)

VARIABLES	Model 1 SPIN/ UNIV	Model 1 FIRM/ UNIV	Model 1 SPIN/ FIRM	Model 2 SPIN/ UNIV	Model 2 FIRM/ UNIV	Model 2 SPIN/ FIRM	Model 3 SPIN/ UNIV	Model 3 FIRM/ UNIV	Model 3 SPIN/ FIRM
Project characteristics									
INDFUND	0.059**	0.055*	0.004						
	[0.025]	[0.033]	[0.033]						
INDFUND_RES							0.041	0.020	0.021
							[0.027]	[0.033]	[0.035]
INDFUND_SMALL							0.851*	1.256*	-0.405
							[0.482]	[0.685]	[0.478]
PUBFUND	-0.010	-0.013	0.003				-0.010	-0.012	0.001
	[0.009]	[0.021]	[0.014]				[0.009]	[0.022]	[0.015]
TTFUND	-0.224	-0.446**	0.222				-0.220	-0.448**	0.228
	[0.189]	[0.176]	[0.248]				[0.189]	[0.204]	[0.276]
INDSHARE				1.780**	1.689*	0.091			
				[0.891]	[0.889]	[0.671]			
PUBSHARE				-0.243	-1.702**	1.458*			
				[0.797]	[0.716]	[0.787]			
TTSHARE				0.019	-1.147	1.166			
				[1.138]	[1.504]	[1.200]			
AVGPUB	-0.116	-0.206***	0.090	-0.059	-0.175***	0.116	-0.106	-0.164***	0.058
	[0.099]	[0.076]	[0.116]	[0.059]	[0.059]	[0.077]	[0.097]	[0.063]	[0.111]
AVGPAT	0.535	0.465*	0.070	0.558	0.385	0.173	0.581*	0.519*	0.062
	[0.350]	[0.277]	[0.261]	[0.392]	[0.306]	[0.274]	[0.353]	[0.298]	[0.262]
Institutional Characteristics									
LN(SPINTOT)	0.849*	0.817***	0.031	0.761*	0.738**	0.023	0.878*	0.856***	0.022
	[0.447]	[0.316]	[0.417]	[0.452]	[0.307]	[0.427]	[0.461]	[0.309]	[0.400]
LN(UNIPATSTOCK)	0.339	-0.313	0.652**	0.321	-0.356	0.677**	0.307	-0.396*	0.703**
	[0.298]	[0.215]	[0.271]	[0.300]	[0.244]	[0.289]	[0.301]	[0.218]	[0.279]
Individual Characteristics									
AGE	0.139	0.164	-0.026	0.202	0.212	-0.010	0.167	0.200	-0.033
	[0.177]	[0.121]	[0.183]	[0.179]	[0.143]	[0.189]	[0.177]	[0.127]	[0.179]
AGE^2	-0.003	-0.003	0.001	-0.004	-0.004	0.000	-0.003	-0.004	0.001
	[0.003]	[0.002]	[0.003]	[0.003]	[0.003]	[0.004]	[0.003]	[0.002]	[0.003]
FEMALE	-1.736**	0.280	-2.015**	-1.474**	0.638	-2.112**	-1.883***	0.122	-2.005**
	[0.770]	[0.630]	[0.978]	[0.653]	[0.671]	[0.931]	[0.684]	[0.707]	[1.012]
PROFESSOR	-0.346	-0.243	-0.103	-0.518	-0.237	-0.281	-0.483	-0.543	0.060
	[0.612]	[0.615]	[0.615]	[0.637]	[0.601]	[0.592]	[0.623]	[0.596]	[0.577]
ELEC	-0.426	-0.404	-0.022	-0.478	-0.385	-0.093	-0.595	-0.550	-0.044
	[0.534]	[0.505]	[0.552]	[0.501]	[0.532]	[0.544]	[0.556]	[0.491]	[0.544]
Constant	-5.705**	-2.003	-3.703	-6.654**	-2.334	-4.320	-6.017**	-2.383	-3.634
	[2.749]	[1.714]	[2.809]	[2.985]	[1.862]	[2.990]	[2.739]	[1.716]	[2.729]
Observations		231			231			231	
Number of Clusters		106			106			106	
log Likelihood		-213.1			-209.4			-209.5	
Pseudo R Squared		0.156			0.171			0.170	

Robust standard errors in brackets, clustered at the individual level. Relative risk ratios are reported.

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Links between inventors and firms (2001-2008)

Firm Characteristics	# firms	Firm is university spin-off	Firm sponsors research	Firm is co-assignee on patent	no link to researcher
micro-entity (1-10 employees)	33	20	1	0	13
small firm (11-50 employees)	18	8	4	3	7
medium-sized firm (51-250)	10	4	2	0	5
large firm (250+)	54	0	24	10	27
Total	**115**	**32**	**31**	**13**	**51**
Firm sponsors research	31	5	-	8	-