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Academic patent value and knowledge transfer in the UK. Does patent ownership matter?

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Abstract

This paper deals with an issue which is particularly relevant in the literature on IPR and university-industry knowledge transfer: is the ownership structure of academic inventions relevant for patent quality and the efficiency of the knowledge transfer process? This question is also particularly significant in Europe where some countries have followed the Bayh-Dole Act example in the USA to increase the involvement level of universities in IP management. The paper uses a novel dataset of academic inventors in the UK, which includes university patents (i.e. patents owned by universities) and corporate patents (i.e. patents signed by academic scientists but owned by private companies) in the period 1990-2001. The UK is an interesting case to study due to the tradition of university involvement in IP management as it was one of the first countries to implement the university ownership model.

The main results may be summarised as follows.

(1) Controlling for observable patent and scientist characteristics, corporate patents received more citations than university patents in the first three years after filing, but (2) this difference is less significant when considering a longer time window. However, (3) there is no knowledge fertilisation across public (university) and private institutions: university patents mainly cite other university patents and the same reasoning applies to corporate patents. Moreover (4) knowledge flows from university patents are even more geographically localised than those from corporate patents. Finally, (5) among scientists' characteristics, a professor's scientific quality and his patenting experience seem to be correlated with patent value.

From a policy prospective, the results in points (1), (2) and (3) cast some doubts on the role of university ownership as an instrument to foster and facilitate knowledge transfer between academia and industry and raise serious questions about the effect of policies towards increasing the role of technology transfer offices in managing academic patents.

1 Introduction

Knowledge produced by academic scientists has been identified as one of the most important channels for technological progress and economic growth. Mainly through the transfer of knowledge, publicly financed science feeds and supports the private sectors, in turn, creating new jobs and generating income (the so-called Third Stream Activity in the UK). The majority of industrial patents are based on findings generated within public research labs (Narin et al. (1997) show that 73 percent of papers cited by US patents owned by the private sector are public in nature, being authored at academic, governmental, and other public institutions). Thus, science policies have paid special attention for a long time to the most efficient tools for improving the exploitation of knowledge created in universities and public research institutions. In particular, in Europe many governments followed the Bayh-Dole Act example from the USA in order to increase the level of university involvement in the management of the inventions produced by their staff (see Geuna and Rossi (2011) for a description of the changes in university IPR regulations in Europe, and Meyer and Tang (2007) for a UK policy context). According to this view, academic scientists should contribute to the innovation activity not only by broadening the science base, but also by producing (patentable) inventions suitable for industrial application.

At the same time universities have been characterised by substantial changes in terms of research funding and have been gradually obliged to diversify the sources of their finance. In many countries public funds have significantly declined (especially in the UK since the mid 1980s)[1] and have been to some extent substituted by competitive funds (Geuna, 2001).

Greater emphasis on IPR issues and the financial straits of public research funds have gradually changed the incentive structure for academic scientists and led them to face an increasing pressure to patent. For this reason an important concern is related to the possible shift of researchers' resources toward more applied research and the patenting of lower quality inventions (Henderson et al., 1998, Mowery et al., 2002). Thus, many scholars have dealt with patent quality issues by looking at their determinants and evolution over time.

This paper intends to contribute to this debate by investigating the value determinants of a sample of UK academic patents. Three main research questions are investigated. (1) Which are the main determinants for academic patent value? (2) Is ownership structure correlated with patent value? (3) To what extent does new technological knowledge produced by academic researchers flow across institutional and national borders?

The main interest in studying UK academic patenting resides in the institutional features of British universities, which place them in between the two extremes of state-run, highly-centralised university systems typical of a large part of continental Europe, and the highly decentralised, largely private US system. While UK universities lack the financial power of private and large public US universities, they are closer to the latter both in terms of administrative autonomy, access to a flexible academic labour market for scientists, and expertise in dealing with IPR issues.

The sample used in this paper is composed of 1376 patents applied for at the European Patent Office (EPO) and invented by academic scientists in the UK between 1990 and 2001.

Patent data cover inventions produced by British academic scientists in active service in 2001, for

[1] Primarily as a result of budget cuts during the Thatcher government (Meyer and Tang, 2007).

which a patent application was filed at the EPO. In particular, the data contain applications submitted not only by scientists and their universities, but also applications by companies, governmental and non-profit organisations, as long as they cover scientists' inventions.

In what follows, we define academic patents as those related to universities through their (academic) inventors rather than university ownership. In particular, we always consider academic patents, and among them we define university patents as those owned by universities, and corporate patents as those owned by private companies.

The empirical results show that patent value, approximated by forward patent citations, is positively correlated with a professor's patenting experience and with his scientific productivity. Moreover, patents invented by academic scientists and owned by the business sectors (corporate patents) have more forward citations in the first years after filing than academic patents owned by a university (university patents), but this difference declines when considering a longer period of time till to disappear. Finally, in terms of knowledge spillovers, some results show that, considering only citations from the business sector, this difference is even increased, casting some doubts on the effectiveness of the policy initiatives recently introduced in Europe aimed at encouraging universities to achieve more patents out of their research and at easing the knowledge transfer to the private sector.

The paper is structured as follows. Section 2 summarises the existing literature on patent value and its determinants, with particular attention to academic patent quality. Section 3 illustrates the data on UK academic patents used for the empirical analysis. Section 4 presents empirical strategies and Section 5 discusses empirical results. Section 6 concludes.

2 Literature review

The concept of patent value is not always precisely defined in the patent literature, as far as it has no intrinsic characteristic to be objective and is not unique at all. A patent may have a huge value for a firm but low for society. In other words, patent value may be analysed through its intrinsic technological properties or through its ability to generate profits for the company applying for it. It is widely recognised, for example, that the patent system has also been used by companies for 'strategic' motives[2], as far as patents may be used as insurance for (potential) future technological space against competitors or, vice versa, to restrict competitors' future technological opportunities and 'submarine' areas of technology where competitors are working (Scott, 2007). Moreover, companies may choose to patent defensively in order to use them in negotiations with other firms (Hall and Ziedonis, 2001). In this case, the value of the patent may be higher for the company than for society[3].

In this paper, because we consider patents produced by academic scientists, we analyse the value of the patent from a social point of view, by estimating the impact that a patent may have on the production and diffusion of knowledge itself. According to this, the social value of a patent concerns the development of public knowledge itself, without taking into consideration expected revenues for the market.

In this context, the classical measures of patent value used in the literature are (1) the number of forward citations, which point out the relevance of the patent for further research, (2) the occurrence

[2] See Orsenigo and Sterzi (2010) for further considerations on the role of patents and their use in different industries.

[3] For example Blind et al. (2009) show that companies' defense strategies in patenting are sources of fewer forward citations to their patents.

(or the number) of backward citations in the search report, which may invalidate the granted process or lead to patent opposition[4], (3) the success of the patent itself, i.e. the patent application acceptance (Guellec and van Pottelsberghe de La Potterie, 2000), (4) the generality of the patent, which shows that it has been important for a broad field of research. At the same time, measures more related to the patent value at the firm level are (5) number of claims[5], which reflects the breadth of technology claimed and imbedded in the patent itself and, related to the number of claims, (6) patent disputes (Lanjouw and Schankerman, 2001; Bessen, 2008), and (7) patent renewal (Pakes and Schankerman, 1984).

In the empirical analysis we use forward patent citations, also because previous studies have shown that these are highly correlated with measures of the social value of the invention (Trajtenberg, 1990, Albert et al., 1991) as well as with its private value (Harhoff et al., 1999, Harhoff and Reitzig, 2004, Hall et al., 2005)[6].

Despite much research on academic patents, little evidence has been provided on the quality of academic patents. However, remarkable exceptions are to be found mostly in the US context, where the debate is mainly concentrated on the effects of the Bayh-Dole Act. Changes in federal laws at the beginning of the 1980s made it significantly easier for universities to claim property rights to discoveries deriving from federal funds, with the consequence that university patenting exploded. Basically, in the US context, the most influential papers on this issue claimed that the importance of overall US university patents declined after 1980 (Henderson et al., 1998), but that this effect would vanish by controlling for the new entry of inexperienced patenters (Mowery and Ziedonis, 2002) and for changes in the intertemporal distribution of citations to university patents (Sampat et al., 2003).

In the European context, only a few works explicitly deal with the quality of academic patents. Sapsalis et al. (2006) and Sapsalis and van Pottelsberghe (2007) for Belgian universities, Czarnitzki et al. (2008, 2011) for German academic patents and Crespi et al. (2010) for a sample of European academic patents (the Patval survey) are exceptions. In all cases the patent quality is proxied by the number of patent citations received by a patent from any subsequent patent application.

Sapsalis et al. (2006) compare 239 corporate and 155 academic patents invented in Belgium between 1985 and 1999 in the biotech field. Their results show that the determinants of patent value are mostly the same. In particular, as found later in Sapsalis and van Pottelsberghe (2007), controlling for age (the newer a patent, the more limited the probability of being cited) and the number of inventors involved in the inventions (larger teams would imply higher expected return), the number of co-assignees and the number of non-patent self-citations to the literature are positive

[4] The classical view of backward citations considers these as a potential determinant of opposition: the patentee has the incentive to put (backward) citations that make the patent more resistant to invalidation problems (Harhoff and Reitzig, 2004). If this might be true from a private point of view, this is clearly not true from a social point of view. A greater number of (backward) citations signifies that the step of novelty of inventive activity is not very high. Moreover, the patent may be derived more from a cumulative process than an innovative idea

[5] The claims in the patent define the property rights protected by the patent; therefore the patentee has the incentive to claim as much as possible in the application, but at the same time the patent examiner may require that the claims be narrowed before granting it.

[6] In particular, Harhoff et al. (1999) analyse the relationship between patent citations and the payment of patent renewal fees, while Hall et al. (2005) study the relationship between patent citations and firm market value. However, other scholars cast some doubts on the use of citations as a measure of patent quality: for example, Bessen (2008) on the one hand shows that highly cited patents are more valuable, but on the other hand, points out that patent citations explain little variance in the value.

correlated with the patent value, whereas non-self-citations to the scientific literature are negatively associated.

Czarnitzki et al. (2008), through a sample of 4973 German academic patents between 1980 and 2003 across all fields of science, find that academic patents are characterised by a higher level of knowledge externalities (measured as forward citations) than the control group of non-academic patents. Moreover, they find that experience matters, to the extent that academic scientists with no previous patenting experience fill out patents of lower value than academic incumbents.

Czarnitzki et al. (2011) find that short term citations (up to 5 years after publication) are associated with corporate ownership, while long term citations (more than 5 years) are linked to university ownership. They interpret this result as a fact that 'corporations tend to source knowledge which yields immediate returns and tend to ignore more basic patents that result in later applications'.

Finally, in the same context, Crespi et al. (2010), through a sample of European academic patents, ask whether a relationship exists between patent ownership and patent value. Their results show that 'there is not much evidence that university-owned patents are more used [...] than university invented-patents that are owned by firms'.

All these studies put their emphasis on patent value, without explicitly considering if and where the academic knowledge is able to spill over and across different types of institutions. In dealing with academic patents an important issue is in fact to assess to what extent they are able to narrow the gap between industry and university.

For this purpose, beyond a mere counting of citations, we are also able to consider from where the citations come. In this vein we use patent citations not only to assess the patent value but also to track the knowledge flows. Disentangling the citations according to their ownership we assess the extent to which university patents are effective in the knowledge transfer process to the business sector.

3 Data description

The data used in this paper were collected during the course of a project sponsored by the European Commission[7]. One of the purposes of the project, called CID, was to create a database on academic patenting for the UK, which contains both applications submitted by universities and applications submitted by companies and not-for-profit institutions as a result of a variety of agreements between such organisations and academic scientists.

The CID-database[8] originates from the EP-INV database, which is part of the larger EP-KITES database and provides information on patents applied for at the EPO, and from the RAE2001 database, which collects information on individual scientists in active service in 2001 in universities and higher education institutions in the UK.

From the EP-INV database we extract the UK-EP-INV database which contains all the UK patents, i.e. all EPO patent applications with at least one inventor residing in the UK.

The UK-EP-INV contains 58,268 UK patent applications between 1990 and 2001. Data fall into four broad categories:

[7] NEST-2006-PATH-Cul, Contract n.: FP6 – 043345

[8] See Guarisco et al., 2009 for a detailed overview of the methodology used.

1. Patent data: priority dates, technological class (IPC, OST7, OST30) and number of claims.
2. Inventor data (name, surname, residence)
3. Applicant data, such as name, country, and nature (business company, university, public research organisation, or individual)
4. Citations (forward and backward)

The RAE2001 database collects information on scientists in active service in 2001. We have data on 60,672 academic researchers and 173 institutions. Biographical information on individuals is limited to department (or research centre) of affiliation, surname and initials of the name. Moreover, the RAE2001 database allows us to retrieve the four publications (title and journal) for each scientist which are used to assess individual scientific productivity[9].

Basically, the identification of academic inventors was obtained in two steps[10]. First, we matched the name from the inventors' names in the UK-EP-INV dataset with the list of researchers in the RAE2001[11] dataset (excluding evident inconsistencies between the professor's discipline and the patent technological class). Then, a web survey confirmed the potential matches, avoiding possible homonymy.

We end up with a sample of 616 confirmed UK academic inventors[12] and we are able to identify 1376 patent applications for a period of 12 years (1990-2001) in which at least one of the UK academic inventors was employed by a university (we label these 'academic patents').

The six most active patenting UK universities (see Table A1 in Appendix) are Oxford University[13] (with 73 patent applications), followed by the University of Manchester (34), Cambridge University (31), the University of Bristol (24), and University College London (23) and Southampton (23). Among the top patenting companies involving academic scientists Zeneca is at the top (with 27 patents), followed by Cancer Research Technology (21) and other UK multinational companies such as Sterix (19), BP Chemicals (16) and British Nuclear Fuels (16). The Medical Research Council (MRC) with 32 patent applications is at the top among governmental institutions, hospitals and other public research centres.

Based upon the DT-7 re-classification of IPC codes proposed by the Observatoire des Sciences et des Techniques (OST, 2008) the most important technological field (see Table A2 in the Appendix) is that of Pharmaceuticals and Biotechnology with around 36 percent of academic patents, followed by Scientific and Control Instruments (21%) and Chemicals and Materials (17%). These figures are similar to those for France and Italy (see Lissoni et al., 2008 for a comparison with the French, Italian and Swedish cases).

[9] Even though individuals are not forced to submit information about their research activity, they have a great incentive to do so, given that the amount of research funding made available to each research unit and department depends strictly upon the ranking produced by the RAE.

[10] The methodology used to build the CID-KEINS database largely follows what was implemented in the case of the KEINS database (Lissoni et al., 2006, 2008).

[11] The Research Assessment Exercise (RAE) is a periodical evaluation of British universities' scientific activities. It is conducted jointly by the Higher Education Funding Council for England (HEFCE), the Scottish Higher Education Funding Council (SHEFC), the Higher Education Funding Council for Wales (HEFCW), and the Department of Education for Northern Ireland (DENI). Its aim consists in grading the quality of academic research and to enable governmental funding bodies to distribute some of their public funds to universities with respect to the quality of research carried out in each department (Review of Research Assessment, 2003).

[12] For further analysis on the characteristics of UK academic inventors, see Meissner and Sterzi (2011).

[13] ISIS Innovation

If similarities exist in terms of technological contents, what differs is the ownership regime. Lissoni et al. (2008) show that in Sweden, France and Italy, the majority – around 61, 72 and 81 per cent respectively – of academic patents are not in the hands of the university, but are owned by the business sector. On the other hand, Thursby et al. (2009) present a different picture for the USA, where private companies hold no more than 25 percent of academic patents.

The UK is in between the two: academic patents owned by the private sector (we label these 'corporate patents') make up 50 percent of the total, while university-owned patents ('university patents') account for 40 percent. Interestingly, if we take into account that before 1993 the British Technology Group (BTG)[14] was public and operating as a brokerage agency in support of universities, these weights seem to be constant over the period considered (see Table 1).

[TABLE 1 NEAR HERE]

The ownership differences between UK and other European countries clearly reflect the institutional diversities. The greater percentage of university-owned patents in the UK is mainly attributed to the tradition of involvement of the university in IP management: the UK was in fact one of the first countries to implement university ownership[15], when in 1977 the Patent Act declares that an employee invention is owned by the employer (in this case, the university). However, a similar IPR regulation takes place in France and in Italy (till 2001), while Sweden adopts systems mainly centered on assigning IPR ownership to the inventor.

Given that, it may be surprising that such a high percentage of academic patents is owned by the business sector. However, different explanations arise: (1) universities in the UK followed considerably different strategies in managing IP; the most well-known case is that of Cambridge University that until 2001 did not enforce fully the university ownership right (Geuna and Rossi, 2011); (2) the effectiveness of the Technology Transfer Office (TTO) and its IP strategies differs across universities: some TTOs may prefer to file as many applications as they can, while others may prefer to seek patent protection only for inventions they consider commercially feasible (Meyer and Tang, 2007); (3) even though university ownership was already the legal default, it was usually weakly enforced (Crespi et al., 2010); (4) the ownership decision may be a result of rational behaviour: academic scientists with valuable ideas may prefer to bypass the TTO and look directly for companies where they can develop their idea, attracted by better equipment and higher royalties.

The next section presents the variables and the econometric model that aims at explaining the quality and knowledge diffusion of UK academic patents.

4 Empirical strategy

To analyse the determinants of the patent quality a cross-section analysis is conducted[16]. The dependent variable of the model is the number of patent citations (FPC), as many authors have used to approximate the patent value (see Section 2).

[14] The BTG share of academic patents is here presented separately from that of other companies, in order to demonstrate its role over the years, which is marked by a sharp decline right after privatisation

[15] For further discussion on university IPR regulations in Europe, see Geuna and Rossi (2011)

[16] Duration models (e.g. event history models) may also be applied but the core of the paper is to evaluate quality and knowledge diffusion without considering its quickness (i.e. the time before the first citation). However, for completeness we also present the Cox proportional hazard model in Section 5.4.

We implement Poisson models which provide a natural way of dealing with high skewness[17] of the dependent variable and at the same time take into account its integer nature. In particular, a negative binomial model is applied to explicitly model the presence of significance over dispersion.

More specifically, we estimate the following negative binomial:

$$E[C|X] = \exp\left[\sum \alpha_l TECH_l + \sum \beta_j YEAR_j + \sum \gamma_j CV_j + \sum d_y VD_y\right]$$

where C is the number of forward citations for the focal patent and X is the vector containing the explanatory variables; TECH is a set of dummy variables for the different technological class l (l=1, 2, ..., 30); YEAR is a set of dummy variables for the different priority year (j=1990,...2001); CV and VD are vectors that contain the control variables and the main determinants respectively.

4.1 Dependent Variable

The basic dependent variable is the number of forward citations received with the exclusion of self-citations at the inventor level[18] - that is, all citations in which the cited and citing patent applications share at least a common inventor - which is our proxy to patent value.

Table 2 shows that corporate patents (academic patents owned by the business sector) are on average cited more extensively (1.26 citations in the first three years following the priority date) than university patents (0.84) in almost all the years considered. The difference is overall statistically significant, even if declining in the last 3 years considered.

[TABLE 2 NEAR HERE]

Of course, patents are not instantaneously cited after their filing: for this reason, the older a patent is the more citations it receives on average. This explains the decreasing number of forward citations since 1995[19].

For robustness, forward citations are computed in two different windows of time: within three and six years following the priority date[20].

Moreover, beyond the mere count of citations, we are also able to consider where the citations come from. In particular, patent citations are also used to track knowledge flows (see among others, Jaffe et al., 1993; Maurseth and Verspagen, 2002; Bacchiocchi and Montobbio, 2010): disentangling the citations according to their ownership we assess the extent to which university patents are effective in the knowledge transfer process to the business sector.

Of course, science policies deserve great importance for the extent to which new technological knowledge produced by academic researchers flows across institutional and national boundaries.

For this purpose, patent citations are disentangled according to their origin - citations from university patents, corporate patents and 'international' patents - in order to assess the diffusion of knowledge into the realm of industry and outside national borders.

[17] Only 31 patents have more than 10 citations, whereas 526 patents have no citations.

[18] By excluding also self-citations at company (applicant) level we get similar values, which are not displayed but are available upon request.

[19] A set of year dummies in the specification controls for this phenomenon.

[20] In the following six years from the priority years, university patents receive on average 1.69 citations, compared to 2.18 for corporate patents. The difference is still significant.

Table 3 shows that on average university-owned patents received more citations only from other university patents. In other words, the knowledge produced within academia seems to be confined to within its borders, raising some doubts for the role of the IPR ownership model as a tool to favor knowledge flows to the private sector. Moreover, results indicate that diffusion seems to be geographically localised: within-country citations are more numerous for both university patents and corporate patents.

Academic inventors of patents owned by business companies are found to hold brokerage positions to the extent that they are able to bridge the academic and industrial communities (Lissoni, 2010).

[TABLE 3 NEAR HERE]

4.2 Controls and Main determinants

Among control variables, we consider the technological class of patents, based upon the OST-30 classification, and 11 year dummies (1991-2001) in order to keep under control the influence of the year in which patents were filed at the EPO and to take into account that older patents have more probability of being cited, ceteris paribus.

Then, we control for the number of inventors (INV) listed in the patent: at a company level this could be seen as a proxy of the importance for the company itself (Sapsalis et al., 2006) and it could also be a proxy for the research effort. The average size in the sample is 3.3 inventors per patent.

The number of claims (CLAIMS)[21] controls for a patent's breadth, which may be the 'value driver' of the patent: Lanjouw and Schankerman (2001) show that the probability for a patent to be disputed increases with its number of claims.

The number of co-assignees (COAS) reflects the collaboration among two or more institutions. The higher the number of co-assignees, the higher is the expected patent value. However, little collaboration seems to take place: only nine percent of academic patents are co-applied for with another assignee (15 percent considering only university-owned patents).

Given the descriptive statistics on patent quality, patent ownership is taken into account. In particular, four dummies are considered: COMPANY (which takes a value=1 if the patent is owned only by the business sector), INDIVIDUAL (=1 if the professor is the owner), GOVERNMENT (=1 if the patent is owned by governmental institutions, hospitals and other public research centres) and BTG (British Technology Group)[22]. The reference case is the University dummy (=1 whenever a university results as one of the patent applicants)[23].

For the extent to which an invention is at least partly based on scientific knowledge we consider non-patent citations (NPCs), i.e. basically citations to scientific journals. NPC is a dummy which equals to 1 as far as a patent application has at least one non-patent citation in the search report.

[21] The claims in the patent define the property rights protected by the patent; therefore the patentee has an incentive to claim as much as possible in the application, but at the same time the patent examiner may require for the claims to be narrowed before granting

[22] The BTG share of academic patents is here presented separately from that of other companies, in order to demonstrate its role over the years, which is marked by a sharp decline right after privatisation

[23] We avoided multiple ownership and decided to follow this rule: whenever a patent has been applied for by a university and another institution at the same time is categorized with the University dummy; the same reasoning applies to the 'government', 'company' and 'BTG' respectively. For descriptive purposes the cases of patents co-applied by university and company are 48 (3.5%).

Quite surprisingly, corporate patents cite the scientific literature more frequently than university patents. However, these results are similar to the findings of Sapsalis et al. (2006), even though they compare academic patents with non-academic patents (patents which do not involve any academic scientists)[24].

We then speculate whether a professor's patenting experience is important for his patent quality. As demonstrated by Mowery et al. (2002) and Czarnitzki et al. (2008), academics learn to patent through experience in patenting. For each patent we build the PROFESSOR' S EXPERIENCE variable which is the number of patents applied for by the professors before the patent considered.

Finally, in order to assess the relationship between patenting and publishing, we control for the academic inventor's intrinsic ability by his SCIENTIFIC QUALITY, which is measured as the average impact factor of the journals of the (four) publications selected for the 2001 RAE[25]. Because this measure reflects the scientific productivity between 1996 (the last RAE before the 2001 RAE) and 2001, in the econometric specification we consider this restricted span of years.

Tables A3 and A4 in the Appendix present the variables description and selected descriptive statistics.

5 Empirical results

Tables 4 and 5 present the econometric results of the model defined in the previous section. We first estimate the academic patent value (Table 4). Then, the forward citations are disaggregated according to their origin to track the knowledge flows (Table 5).

5.1 Patent value

Table 4 shows the result of the Negative Binomial for equation 1. The first remarkable result is that corporate patents receive on average about 33 percent (according to the forward patent citations in the first three years after the patent priority year) more citations than the university patents. However, this difference goes down to 14 percent (and significant only at the 85% level) when we consider six years as a window of time. These results confirm our findings on the comparison of means (see the previous section) and are in line with Czarnitzki et al. (2011) who find that short term citations (up to five years after publication) are associated with corporate ownership, compared to long term citations (more than five years) with university ownership. Government, individual and BTG patents do not seem to differ from University patents.

Nevertheless, we have to be careful in interpreting these results correctly to the extent that patent ownership may suffer from the endogeneity problem: the ownership variable may in fact be the result of professors' rational behaviour. It is possible that professors with more valuable ideas may prefer to bypass the university TTO and directly seek a firm where the idea can be developed with better equipment and higher royalties.

[24] They suggest that academic patents may protect more emerging technologies that are by definition less documented in the scientific literature.

[25] Whenever a patent has been applied for by two professors in the database we assigned the maximum of the average impact factor.

Another interesting result is that professors with lower patent experience file patents of lower quality than academic incumbents. PROFESSOR'S EXPERIENCE is positive and significant according to the FPC(6).

Collaborations do not seem to matter as the number of co-assignees is not associated with a positive and significant parameter in any of the models.

Contrary to our expectations, having a non-patent citation (NPC) is associated with a lower quality; however this result is in line with the findings of Sapsalis et al. (2006). They suggest that NPCs may have a negative or non-significant impact because scientific papers are available to all inventors, not providing any advantage to the citing patent.

The final important value determinant considered is scientific quality, measured as the average impact factor of the scientific journals of the articles selected for the 2001 RAE. We recall that this measure reflects scientific productivity between 1996 and 2001 (the last RAE before the 2001 RAE), and so in the econometric specification we consider only a restricted span of years (1996-2001). Our results show a positive correlation between patent quality and scientific quality. In all the models SCIENTIFC QUALITY is positive and significant.

With respect to control variables our results are in line with the literature: everything equals, (1) older patents receive more citations than younger patents, as evinced by the year dummies; (2) the number of claims is positively correlated; (3) the size of the academic research team seems to have a non-significant influence on the patent value. The latter result deserves an explanation. For non-academic patents the size of the research team (measured as the number of inventors listed in the patent application) usually has a positive correlation with the patent value (see, among others, Guellec and van Pottelsberghe, 2000; Sapsalis et al., 2006): in a competitive framework, because the number of researchers represents a cost for the company it is reasonable to expect a higher patent value. However in the academic context, as pointed out by Liebeskind and Oliver (1999), scientists prefer to limit the size of their research teams to minimize disagreements and disputes over claims and IPRs.

[TABLE 4 NEAR HERE]

5.2 Knowledge transfer

For public policy it is a matter of great importance the degree to which new technological knowledge produced by academic researchers flows across institutional and national boundaries.

If patent citations have been extensively used as a proxy for patent value, they have also been used to track knowledge flows. In this vein we are able not only to assess the patent value but also to evaluate where the patent-related academic knowledge goes.

We disentangle forward patent citations according to their ownership and location origin: in particular we consider University and Company patent citations to refer to the ownership, and International and National to the location (residence) of the inventors. A simple look at the distribution of patent citations by their origin is eloquent: considering only citations from patents applied for by university and companies, 7% of citations to university patents come from corporate patents (i.e. 93% of citations received come from other university patents), while 5% of citations to corporate patents come from university patents (i.e. 95% of citations received come from other patents applied by companies). These figures show clearly the difficulty the knowledge spills over different institutional boundaries.

From the econometric point of view, Equation 1 is then estimated considering the four measures of knowledge spillovers as dependent variables. The same value determinants and control variables are considered; in particular, our attention is addressed to the ownership dummies. To be clear, the dependent variables (see Table 5) are the number of forward citations within six years following the priority date respectively from patents applied by university (Column 1), by companies (Column 2), patents with non-UK inventors (Column 3) and with only UK inventors.

Table 5 - in the first column - shows that, controlling for other determinants, corporate patents receive on average about 98 percent less university citations than university patents. This is strong evidence of little (almost non-existent) knowledge transfer from the business sector to academia. It seems that university patents build their knowledge only looking at the pool of knowledge already existing within academia.

At the same time, corporate patents receive more citations (more than three times) from corporate patents, demonstrating strong evidence of little knowledge transfer from academia to the business sector. The company dummy in column 2 is positive and highly significant. This result should be driven by the interpersonal links among inventors (Balconi et al. 2004) which diffuse information within the scientific community: each researcher has a number of links (his co-inventors) which are basically the channel through which the knowledge spills over and co-invention links allow for some degree of knowledge transfer (Lissoni, 2010). Hence, because corporate patents generally involve not only academic researchers but also researchers working in the business sector, the presence of the latter type of researchers facilitates knowledge transmission to other firms.

Together, these results produce a picture where there is no knowledge fertilisation across public (university) and private institutions and cast some doubts on the role of university ownership as an instrument for fostering and facilitating knowledge transfer between academia and industry.

Finally, in columns 3 and 4 of Table 5 we compare the geographical reach of knowledge flows from university and corporate patents. In column 3, the dependent variable is the number of forward citations from non-UK patents, that is, patents invented by inventors residing abroad. The results clearly show that knowledge flows from university patents are more geographically localised than those from corporate patents: corporate patents receive on average about 48 percent more international citations than university patents. At the same time, this difference disappears when considering only national citations.

[TABLE 5 NEAR HERE]

5.3 Robustness check (1). Granted patents

In the previous analysis all data refer to applications, and therefore include both granted and non-granted patents. This decision was followed mainly for two reasons: (1) given that the average time from filing to granting is almost 4 years, and even more when considering the priority year, this choice would have created some bias for more recent patent applications; (2) using patent applications instead of granted patents would allow us also to include less-experienced academic inventors, i.e. those who try to patent without success.

However, the previous results are robust – even stronger – even considering only granted patents. The results are displayed in Table A5 in the Appendix.

5.4 Robustness check (2). Survival analysis models

As far as we have studied the impact of covariates on the number of forward citations, we have considered the Poisson models. However, in dealing with the value of academic patents, beyond the number of citations, it is also possible to analyse the time a patent requires to be cited. For this purpose, the survival analysis model allows us to study durations from an initial date (which is the priority date of the patent) until the date of the event (the priority date of the citing patent, if any). The priority dates of patents in our sample run from January 1, 1990 and December 31, 2001. The terminal date of observation is August 30, 2008; the patents without citations by August 30, 2008 were considered as censored at that date. Hence, our data consist of a cross-section of durations $t1, t2, ..tn \in T$ and allow us to estimate the probability that the event 'citation' appears in the next period.

We assumed a proportional hazard model and opted for a semi-parametric Cox model that enables the effect of different variables on the hazard to be determined.

In particular, the hazard function hi(t) of a patent i is expressed as:

$$h_i(t) = h_i(t, x_i) = h_0(t) \exp\left(x_i', \beta\right)$$

where $h_0(t)$ is an unspecified baseline hazard function representing the probability of being cited conditional on the fact that the patent was not cited until time t, x_i is a vector of explanatory variables for the *i-th* patent and β is the vector of unknown parameters to be estimated. Positive coefficients imply that the hazard rate increases and the corresponding probability of survival (i.e. being without citations) decreases.

To control for the cohort and the technological class effect we estimated a semi-parametric Cox model which is stratified according to the year and OST30 technological class of the cited patent. The assumption is that the parameters entering the Cox likelihood are the same for every cohort and technological class: the stratified Cox model allows the form of the underlying hazard function to vary across levels of stratification variables.

The test of proportional-hazards assumption indicates an absence of evidence to contradict the proportionality assumption.

Table 6 displays the results of the Cox model and shows how the characteristics of academic patents are related to the citation probability. The results are in line with the Poisson models. The Company ownership dummy has a positive and significant effect on the hazard rate: corporate patents are generally more cited than the baseline university-owned ones. Finally, scientific quality and the number of claims again have a positive and significant effect on the probability of being cited.

[TABLE 6 NEAR HERE]

6 Conclusions and further research

This paper has presented an empirical analysis of the determinants of patent value and knowledge diffusion in a sample of UK academic patents, that is, patents where at least one of the inventors is a UK academic scientist. In particular, it has considered patent applications submitted not only by scientists and their universities, but also those by companies, governmental and non-profit organisations, as long as they cover the academic scientists' inventions.

The first objective of this paper was to assess the determinants of university patent value (proxied by forward patent citations). The second objective was to evaluate to what extent new technological knowledge produced by academic scientists flows across institutional and national borders.

Regarding the first research question, we found that, controlling for priority years and technological classes, a professor's patent experience and scientific quality are correlated with the patent value. That being so, the role of prolific academic inventors and scientific stars must be carefully analysed.

Then, an important role is played by patent ownership: corporate patents - academic patents owned by companies – receive on average more patent citations than university patents - academic patents owned by universities. In detail, according to the econometric results, corporate patents receive on average about 33 percent more citations than the university patents in the first three years after the patent priority year. However, this difference goes down to 14 percent (and significant only at the 85% level) when we consider a longer window of time.

. This result may be partly explained by the fact that UK universities, as well as other European universities, suffer from a lack of tradition and experience in IP management. Thus, the role of TTOs would be an important factor to control for in further research.

The second research question was related to what extent new technological knowledge produced by academic researchers flows across institutional and national boundaries. Our results showed that there is no knowledge fertilisation across public (university) and private institutions: university patents cite mainly other university patents and the same reasoning applies to corporate patents. Moreover, knowledge flows from university patents are even more geographically localised than those from corporate patents.

From a policy prospective, these results cast some doubts on the role of university ownership as an instrument to foster and facilitate knowledge transfer between academia and industry and raise serious questions about the effect of policies towards increasing the role of technology transfer offices in managing university patents.

One justification for university ownership is that it manages the intellectual property for the academic inventor as it performs a service as intermediary between inventor and potential licensees. The general idea is that the university, through the TTO, is able to reduce the asymmetric information problem. Given the lower costs of search, because of specialisation and lower opportunity cost of time, it has knowledge superior to that of the inventor as to which firms might be interested in the invention. Moreover, through its reputation, the university may also act as a signal to private business.

However, if the university does not have superior knowledge and if the academic inventor already has a strong reputation and connections with the private sector, university ownership may not be optimal, perhaps resulting in less effort by the inventor. Furthermore university ownership may decrease the exchange of knowledge between the academic and business sector as far as academic inventors of patents owned by business companies are found to hold brokerage positions.

To this extent, an alternative model which vests ownership with the inventor and then leaves him the possibility to choose the commercialisation path for the invention (Kenney and Patton, 2009) may be preferred.

Although this analysis improves on the existing literature by considering a novel dataset on UK academic patents to illustrate the determinants of patents' value and their relationship with the ownership regime, it does not claim to provide a complete picture of the ownership-quality relationship. In particular, we do not assess whether the relationship between patent value and ownership is causal as we do not question for what reasons academic patents are owned by university or private sector. The ownership decision may be the result of rational behaviour, bringing to light endogeneity problems. This constraint must be taken into account when interpreting the results and further research into this is not only desirable but also necessary.

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Table 1.
Number of academic patents by ownership and years (%)

	University		Corporate		Government		Individual		BTG		Tot. Patents
1990	8	*14%*	33	*59%*	7	*13%*	1	*2%*	7	*13%*	56
1991	16	*28%*	23	*40%*	7	*12%*	2	*4%*	9	*16%*	57
1992	16	*27%*	27	*45%*	6	*10%*	1	*2%*	10	*17%*	60
1993	13	*22%*	40	*69%*	4	*7%*	0	*0%*	1	*2%*	58
1994	39	*37%*	59	*56%*	4	*4%*	0	*0%*	4	*4%*	106
1995	43	*38%*	60	*54%*	8	*7%*	0	*0%*	1	*1%*	112
1996	48	*38%*	59	*46%*	10	*8%*	5	*4%*	6	*5%*	128
1997	56	*40%*	77	*55%*	5	*4%*	2	*1%*	1	*1%*	141
1998	85	*50%*	74	*44%*	7	*4%*	3	*2%*	1	*1%*	170
1999	92	*45%*	103	*50%*	8	*4%*	0	*0%*	2	*1%*	205
2000	92	*47%*	87	*45%*	4	*2%*	6	*3%*	5	*3%*	194
2001	42	*47%*	46	*52%*	1	*1%*	0	*0%*	0	*0%*	89
All years	550	*40%*	688	*50%*	71	*5%*	20	*1%*	47	*3%*	1376

Table 2.
Patent quality (FPC 3) by ownership: mean values (# of patents)

	University Patents		Corporate Patents		diff= mean U- mean C	Ha: diff < 0 sig.
1990	1.50	*8*	1.15	*33*	*0.35*	
1991	0.75	*16*	0.70	*23*	*0.05*	
1992	0.63	*16*	1.04	*27*	*-0.41*	
1993	0.77	*13*	1.98	*40*	*-1.21*	
1994	0.74	*39*	1.25	*59*	*-0.51*	*
1995	1.19	*43*	0.88	*60*	*0.30*	
1996	0.69	*48*	1.69	*59*	*-1.01*	***
1997	1.05	*56*	2.01	*77*	*-0.96*	*
1998	0.89	*85*	1.34	*74*	*-0.44*	*
1999	0.89	*92*	1.10	*103*	*-0.20*	
2000	0.64	*92*	0.77	*87*	*-0.13*	
2001	0.64	*42*	0.98	*46*	*-0.34*	
Total sample	**0.84**	**550**	**1.26**	**688**	***-0.42***	*******

Self citations at inventor level are excluded

Table 3.
Patent quality and knowledge flows by ownership (mean values)

	University Patents		Corporate patents		diff= mean U- mean C	Ha: diff ≠ 0 sig.
FPC (3 years)	0.84	550	1.26	688	*-0.42*	***
FPC (6 years)	1.69	550	2.18	688	-0.48	***
FPC (3 years) excluding self-citations at applicant level	0.75	550	1.13	688	*-0.37*	***
FPC (6 years) excluding self-citations at applicant level	1.56	550	1.98	688	-0.41	**
FPC (6 years from UNIVERSITY patents)*	1.57	550	0.003	688	1.57	***
FPC (6 years from CORPORATE patents)*	0.11	550	1.70	688	-1.18	***
FPC (6 years from NON UK patents)**	0.62	550	0.99	688	-0.37	***
FPC (6 years from ONLY UK patents)***	1.06	550	1.18	688	-0.11	

Self-citations at inventor level are excluded; * only UK applicants are considered, patents applied for by individuals are not considered; ** patents with at least one non-UK inventor; *** patents with only UK inventors.

Table 4.
Econometric results (A): Forward patent citation determinants

	Model 1 FPC(3) [All sample]	**Model 2** FPC(6) [All sample]	**Model 5** FPC(3) [1996-2001]	**Model 6** FPC(6) [1996-2001]
Quality determinants				
Professor's experience	0.010	0.019***	0.014	0.021**
	(0.0087)	(0.0072)	(0.0099)	(0.0084)
CAOS	0.075	0.042	-0.024	-0.072
	(0.090)	(0.075)	(0.11)	(0.089)
Ownership (Ref: University)				
Company	0.29***	0.13†	0.22*	0.070
	(0.10)	(0.084)	(0.12)	(0.10)
Government	0.13	-0.035	0.071	-0.18
	(0.22)	(0.18)	(0.30)	(0.26)
Individual	0.091	-0.018	0.44	0.44
	(0.48)	(0.38)	(0.58)	(0.46)
BTG	0.017	-0.054	0.11	0.078
	(0.28)	(0.22)	(0.43)	(0.37)
NPC	-0.29*	-0.41***	-0.025	-0.19
	(0.15)	(0.13)	(0.20)	(0.17)
SCIENTIFIC QUALITY			0.043***	0.035***
			(0.013)	(0.011)
Control Variables				
INV	0.045*	0.025	0.095***	0.062**
	(0.027)	(0.023)	(0.033)	(0.029)
CLAIMS	0.020***	0.021***	0.019***	0.019***
	(0.0037)	(0.0031)	(0.0043)	(0.0037)
1990	*Ref*	*Ref*		
1991	-0.56*	-0.40		
	(0.33)	(0.26)		
1992	-0.27	-0.064		
	(0.31)	(0.24)		
1993	0.040	0.082		
	(0.30)	(0.24)		
1994	-0.21	-0.28		
	(0.27)	(0.22)		
1995	-0.29	-0.32		
	(0.27)	(0.22)		
1996	-0.022	-0.27	0.88***	1.17***
	(0.27)	(0.22)	(0.25)	(0.22)
1997	-0.025	-0.34	0.75***	0.98***
	(0.26)	(0.21)	(0.23)	(0.20)
1998	-0.26	-0.57***	0.61**	0.83***
	(0.26)	(0.21)	(0.24)	(0.20)
1999	-0.48*	-0.93***	0.34	0.44**
	(0.26)	(0.21)	(0.23)	(0.20)
2000	-0.59**	-1.04***	0.26	0.35*
	(0.26)	(0.21)	(0.24)	(0.20)
2001	-0.75**	-1.33***		
	(0.30)	(0.25)	*Ref*	*Ref*
Constant	-0.37	0.71**	-1.30***	-0.58
	(0.39)	(0.31)	(0.45)	(0.38)
Fields dummy (OST 30)	yes	yes	Yes	yes
Lnalpha	0.53***	0.24***	0.47***	0.23***
	(0.080)	(0.065)	(0.10)	(0.086)
Log Likelihood	-1861.43	-2487.49	-1230.06	-1561.41
Observations	1376	1376	927	927

Self-citations at the inventor level are excluded; levels of significance (probability thresholds) :†<15%, * <10%, ** <5%, *** <1%

Table 5.

Econometric results (B): Forward patent citation determinants by type

COEFFICIENT	**Model 1** **FPC** UNIVERSITY	**Model 3** **FPC** COMPANY	**Model 5** **FPC** INTERNATIONAL	**Model 7** **FPC** NATIONAL
Quality determinants				
Professor's experience	0.020	0.017	-0.0027	0.031***
	(0.013)	(0.013)	(0.0098)	(0.0077)
COAS	0.065	1.68***	0.13	-0.027
	(0.16)	(0.26)	(0.10)	(0.091)
Ownership (Ref: University)				
Company	-6.34***	3.91***	0.38***	-0.023
	(0.71)	(0.27)	(0.11)	(0.093)
Government	-2.14***	2.16***	0.21	-0.20
	(0.34)	(0.37)	(0.24)	(0.20)
Individual	-18.8	-28.2	0.15	-0.21
	(2009)	(615)	(0.53)	(0.41)
BTG	-19.1	3.01***	-0.13	-0.071
	(1470)	(0.42)	(0.32)	(0.23)
NPC	-0.18	-0.83***	-0.24	-0.57***
	(0.24)	(0.22)	(0.17)	(0.15)
Control Variables				
INV	-0.049	0.010	0.017	0.024
	(0.048)	(0.038)	(0.030)	(0.025)
CLAIMS	0.018***	0.025***	0.022***	0.020***
	(0.0056)	(0.0054)	(0.0040)	(0.0034)
Constant	-0.89	-5.59***	-0.25	0.28
	(0.77)	(0.67)	(0.42)	(0.34)
Years dummy	yes	yes	yes	yes
Fields dummy (OST 30)	yes	yes	yes	yes
lnalpha	0.35***	0.99***	0.69***	0.19**
	(0.11)	(0.085)	(0.088)	(0.084)
Log Likelihood	-1011.7363	-1697.8257	-1608.1583	-1911.7918
Observations	1376	1376	1376	1376

Self citations at the inventor level are excluded; levels of significance (probability thresholds) :†<15%, * <10%, ** <5%, *** <1%

Table 6.
Robustness check: Cox (time to citation)

COEFFICIENT	**Model 1** FPC	**Model 2** FPC
Quality determinants		
Professor's experience	0.0100	0.011
	(0.0075)	(0.0087)
COAS	0.092	0.096
	(0.082)	(0.091)
Ownership (Ref: University)		
Company	0.23***	0.25**
	(0.090)	(0.11)
Government	-0.35*	-0.28
	(0.20)	(0.27)
Individual	0.027	-0.071
	(0.38)	(0.45)
BTG	-0.0099	0.084
	(0.24)	(0.40)
NPC	-0.29**	-0.086
	(0.14)	(0.18)
SCIENTIFIC QUALITY		0.023**
		(0.011)
Control Variables		
INV	0.020	0.035
	(0.024)	(0.032)
CLAIMS	0.010***	0.0065*
	(0.0031)	(0.0038)
Log Likelihood	-1609.997	-1084.4268
Test of proportional-hazard assumption (p-value)	0.5887	0.0735
Observations	1332	896

Self-citations at the inventor level are excluded; levels of significance (probability thresholds) :†<15%, * <10%, ** <5%, *** <1% (robust standard errors in parenthesis)

APPENDIX

Table A1.
Top applicant by ownership type

Corporate Patents	
ZENECA	27
CANCER RESEARCH CAMPAIGN TECHNOLOGY	21
STERIX	19
BP CHEMICALS	16
BRITISH NUCLEAR FUELS	16
University Patents	
ISIS INNOVATION	73
UNIVERSITY OF MANCHESTER	34
CAMBRIDGE UNIVERSITY	31
UNIVERSITY OF BRISTOL	24
UNIVERSITY COLLEGE LONDON	23
UNIVERSITY OF SOUTHAMPTON	23
IMPERIAL COLLEGE OF SCIENCE	22
Government (+ hospitals and + PROs) patents	
MEDICAL RESEARCH COUNCIL	32
SECRETARY OF STATE FOR DEFENCE	20
NATURAL ENVIRONMENT RESEARCH COUNCIL	2
ST. GEORGE'S HOSPITAL MEDICAL SCHOOL	2
BTG	
BTG	47

Table A2.
Technological distribution of academic patent applications

OST 7 Technological classes	
ELECTRONICS	13%
INSTRUMENTS	21%
CHEMISTRY-MATERIALS	17%
PHARMACEUTICALS-BIOTECHNOLOGIES	36%
PROCESS ENGINEERING	4%
MECHANICAL ENGINEERING	1%
CONSUMER GOODS-OTHERS	1%

Table A3.
Variable and data description

Name	Description
Dependent Variables	
FPC (3)	Number of forward citations, excluding self-citations at the inventor level (citation lag of 3 years considered)
FPC (6)	Number of forward citations, excluding self-citations at the inventor level (citation lag of 6 years considered)
Quality Determinants	
PROFESSOR' S EXPERIENCE	Number of patents previously applied for by the academic inventor at the time of the patent
COAS	Number of co-assignees
Ownership	Different dummies which correspond to different patent ownership: University, Corporate, Government, Individual and BTG patents are considered
NPC	Dummy=1 if there is at least one non-patent literature citation in the search report
SCIENTIFIC QUALITY	Average impact factor of the journals of publications sent to the RAE 2001
Controls	
Year dummies	11 year dummies (1991-2001)
OST 30	OST technological classification (30 classes)
INV	Number of inventors listed in the patent.
CLAIMS	Number of claims in the patent application.

Table A4.
Summary Statistics

	Obs.	Mean	Std. Dev.	Min.	Max.
Dependent Variables					
FPC (3)	1376	1.08503	2.11197	0	25
FPC (6)	1376	1.99346	3.25732	0	40
Quality Determinants					
PROFESSOR' S EXPERIENCE	1376	3.7689	5.36402	0	29
COAS	1376	1.14608	0.58193	1	13
University	1376	0.39971	0.49002	0	1
Company	1376	0.5	0.50018	0	1
Government	1376	0.0516	0.2213	0	1
Individual	1376	0.01453	0.11972	0	1
BTG	1376	0.03416	0.1817	0	1
NPC	1376	0.119186	0.3241251	0	1
SCIENTIFIC QUALITY*	927	5.09425	4.95312	0	29.567
INV	1376	3.30087	1.74428	1	14
CLAIMS	1376	21.2602	12.9058	0	84

* 1996-2001.

Table A5.
Forward patent citation determinants (granted patents)

COEFFICIENT	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
	FPC(3)	FPC(6)	FPC(3)	FPC(6)	**FPC** (University)	**FPC** (Company)	**FPC** (Non-UK)	**FPC** (UK)
Quality determinants								
Professor's experience	0.023**	0.020**	0.024*	0.026**	0.024†	0.020	0.0015	0.028***
	0.012	0.0097	0.013	0.011	0.016	0.018	0.013	0.01
COAS	0.098	0.032	-0.094	-0.12	0.18	1.98***	0,11	-0.038
	0.11	0.09	0.13	0.11	0.2	0.35	0.13	0.11
Ownership (Ref: University)								
Company	0.39***	0.18*	0.39**	0.096	-5.96***	4.41***	0.48***	0.0056
	0.13	0.11	0.17	0.14	0.72	0.39	0.15	0.11
Government	0.028	-0.19	0.034	-0.33	-2.18***	1.39	0.035	-0.32
	0.26	0.21	0.37	0.31	0.39	0.43	0.29	0.23
Individual	0.37	0.31	1.15*	0.86†	-18.9	-30.0	0.57	-0.0096
	0.62	0.48	0.68	0.55	3063	508	0.67	0.49
BTG	0.14	-0.17	0.39	0.013	-19.7	2.00***	-0.2	-0.22
	0.36	0.29	0.91	0.77	2124	0.68	0.43	0.3
NPC	-0.36†	-0.43**	-0.21	-0.28	0.16	-1.04***	-0.23	-0.56***
	0.22	0.18	0.31	0.26	0.34	0.3	0.24	0.2
SCIENTIFIC QUALITY			0.051***	0.049***				
			0.018	0.015				
Control Variables								
INV	0.038	0.017	0.11***	0.066*	-0.09†	-0.003	0.026	0.0038
	0.036	0.029	0.044	0.037	0.06	0.049	0.039	0.031
CLAIMS	0.022***	0.022***	0.021***	0.019***	0.016**	0.033***	0.025***	0.017***
	0.0048	0.004	0.0058	0.005	0.0065	0.0069	0.0052	0.0042
Constant	-0.25	0.83**	-1.32**	-0.52	-1.13	-2.22***	-0.12	0.37
	0.33	0.37	0.59	0.49	0.87	0.64	0.49	0.39
Fields dummy (OST 30)	yes	yes	yes	yes	yes	yes	yes	yes
Years dummy	yes	yes	yes	yes	yes	yes	yes	yes
lnalpha	0.55***	0.12	0.28**	0.067	0.10	2.41***	0.55***	0.051
	(0.10)	(0.08)	(0.14)	0.12)	(0.15)	(0.26)	(0.12)	(0.1)
Log Likelihood	-1111.72	-631.48	-1486.92	-825.35	-551.15	-788.94	-920.46	-1198.45
Observations	756	756	458	458	756	756	756	756

Self-citations at the inventor level are not considered; levels of significance (probability thresholds) :†<15%, * <10%, ** <5%, *** <1%