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THE ROLE OF EARLY CAREER FACTORS IN ACADEMIC PATENTING

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The role of early career factors in academic patenting.

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Abstract

This paper explores the characteristics of persistent academic inventors and how they are influenced by their personal attributes, PhD institution, and first invention. Using a novel dataset on 555 UK academic inventors, we find that the quality of the first invention is the best predictor for subsequent participation in the patenting process. We further find evidence for a positive training effect whereby researchers that were trained at universities that had already established commercialisation units have a higher propensity to patent persistently. In addition, researchers that gained first patenting experience in industry are able to benefit from stronger knowledge flows and receive more citations than their purely academic peers.

Keywords: Academic inventors, University patents, Persistent innovation

JEL codes: L24; 031; 032; 034

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1. INTRODUCTION

Persistent innovation is an exceptional phenomenon considering that the majority of inventors only ever patent once (Narin and Breitzman, 1995). Persistent inventors appear not only to be continuously involved in inventive research, but also to continuously turn their inventions into patents. This is remarkable, especially if we consider that the majority of both firms and R&D employees never patent (Geroski et al., 1997; Lissoni et al., 2008).

There is evidence that such productive individuals are very important for technological advancement (see Gay et al., 2008). Zucker, Darby and co-authors (1998, 2002), for instance, have repeatedly pointed out the role of star scientists for firm success. They showed that firms collaborating with academic stars produce more innovations and grow more rapidly than other firms. Also within a firm, Rothwell (1992) identified certain key individuals that contribute most to a firm's success. In this process, the characteristics of the inventor are the main determinants of the private economic value of an invention and are more important than the characteristics of the organization (Gambardella et al., 2008). These key performers additionally exert a positive effect on their peers[1]. They may act as role models and thereby trigger more commercial activity amongst their peers (Bercovitz and Feldman, 2008; Goktepe-Hulten, 2008; Stuart and Ding, 2006).

Despite a long history of empirical research in innovation and patenting processes, it is still difficult to identify these successful individuals and to nurture them from the start. Moreover, considering the important role and considerable increase of patenting at universities it is of particular interest to better recognise and retain persistent academic inventors[2]. Patenting activity at

[1] In a recent paper, Azoulay et al. (2010) describe "superstars are an irreplaceable source of ideas" and find strong evidence for a positive effect of academic stars on the publication records of their co-authors.

[2] There has been a considerable increase in the importance of university patenting in Europe and new evidence of high levels of participation of academic scientists in patenting activity (Geuna and Nesta, 2006; Lissoni et al., 2008).

universities is highly skewed[3] with the majority of academics never patenting (Agrawal and Henderson, 2002; Lissoni et al., 2008). Academics that have once entered the patenting process (i.e. have shown that they have some propensity to patent) exhibit great differences in their ability to repeatedly recognize patenting opportunities and to take advantage of these. In view of the continuous focus of policy makers on the successful appropriation of research and the importance of star scientists for the advancement of knowledge, it is of interest to identify those factors that explain persistent invention activity of university researchers.

In this paper we look at the patenting record of a sample of 555 inventors working at universities in the UK from the CID-KEINS database using several measures of productivity. The first measure is the simple count of all patent applications of an inventive university researcher up to 2002; the second measure is the count of patent applications filed while she was working in academia; the third is the count of citations received for applications filed since the start of her academic career.

All three measures return similar results and indicate that the characteristics of the first patent are the most important predictor of invention persistency. Researchers whose first patent was granted and received a large number of citations are more likely to remain active inventors. Highly cited patents have been associated with higher economic value (Gambardella et al., 2008) and may hence generate a *signalling effect* by increasing an academic's visibility status (Jensen and Thursby, 2001), which in turn can help to attract consulting and research contracts with industry (Owen-Smith and Powell, 2001), providing the necessary financial impetus for future innovative research (Link et al., 2007; Meissner, 2011). Hence, first success might confirm a researcher's dissemination strategy, earning it a place in the reward system of science (Dasgupta and David, 1994).

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[3] Breschi et al. (2008) examining the patenting activity of Italian academic inventors find that 60.2% of professors in their sample signed one patent and only 8.6% more than five.

We also find evidence for a *training effect*. Researchers that undertook their PhD studies at a university that had already implemented mechanisms to support technology transfer at the time of the PhD, have a higher propensity to patent persistently throughout their career. This supports findings by Anderson and Rossi (2010), who, in a survey of 46 UK universities, found university participation in various IP marketplaces (proprietary and non-proprietary) to be significantly affected by the presence of an internal TTO. Bercovitz and Feldman (2008) also showed that social imprinting at PhD level increases a researcher's willingness to patent. Many authors have underlined that institutions, such as universities and departments, by transmitting a particular set of behaviours and regulations, are able to shape individuals sharing the same environment with similar attitudes. Kenney and Goe (2004), for example, analysing institutional histories at the University of California, Berkley, and Stanford University, explain differences in professorial entrepreneurship patterns, which are higher at Stanford than at UCB as a consequence of different culture, ethos and norms in which professors were embedded.[4]

We further find evidence for a positive effect of commercial socialisation in industry on persistent inventorship. Researchers that have been involved in patenting before joining academia produce more patents and are more cited than their purely academic colleagues. Hence, hires from industry may be better able to identify inventions with high economic potential or benefit from networks established during their time in industry, as reflected in stronger knowledge flows (Agrawal et al. 2006; Dietz and Bozeman, 2007).

Finally, we find no evidence for a significant relationship between what we might call *intrinsic scientific ability* and patenting persistency. The quality of research published during the early stages of one's career, usually stemming

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[4] This is in concordance with an example quoted in Stuart and Ding (2006: 105): "Nathanson and Becker showed that even socially conservative physicians sometimes provided abortion services, but only when they worked in medical offices dominated by liberal obstetricians—a finding demonstrating both the situational dependence of standards of professional conduct and the role of workplace social influences on the formation of beliefs about the appropriateness of controversial practices."

from PhD research, does not predict patenting later in the career. Prior research has found a positive correlation between publications and commercialisation (Azoulay et al., 2007; Breschi et al., 2005; Carayol, 2007, Zucker et al. 1998), however, we show that this effect may only be true for later stages of the career. It does not help to recognise potential future patenting stars.

The remainder of the paper is structured as follows: Section 2 discusses the importance of signalling. Section 3 describes the data and gives some descriptive statistics. Section 4 explains the methods and presents the results, and section 5 discusses and concludes.

2 ACADEMIC'S INCENTIVES FOR SIGNALLING

Academic research increasingly depends on the acquisition of external grants to support the growing costs of lab equipment and research assistance. The ability to attract extramural funding very often is reflected in increased research productivity and an accelerated career path[5]. Academics thus have an incentive to signal their scientific ability and the relevance of their research to prospective collaborators and funders.

An academic's efforts and ability cannot be observed directly and instead rewards and grants have to be based on observable research outcomes (Dasgupta and David, 1994). Publications in scientific journals can provide such a platform for signalling one's ability and expertise and are thus an important criterion in the allocation of public research funding.

For many prospective sponsors and collaborators market relevance and industrial applicability of an academic's research is of explicit importance

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[5] Breschi et al. (2008), for example, evaluating empirically the consequences of patenting for the scientific output of academic scientists, find that patenting has positive effects on the subsequent publication output to the extent that is driven by the increased availability of financial resources from the private sector.

(Pavitt, 2001) and uncertainty about applicability of scientific research could particularly deter sponsors from industry. Patenting can be an indicator of the market relevance of academic research adding to a researcher's purely scientific work to enable her to attract more funding and grants (Owen-Smith and Powell, 2001)[6]. It can further attract funding from industry directly aimed at the commercialisation of these early stage inventions (Jensen and Thursby, 2001), providing financial resources that can also complement their own research (Lee, 2000).

Patents, further, might indicate a researcher's acceptance of proprietary forms of dissemination (Bercovitz and Feldman, 2008). If research findings can be released as publications but also appropriated through patenting[7], then academics that engage in patenting also signal their readiness to commit to technological research and industry collaboration (Dasgupta and David, 1994). Patenting can thus act as a signal for a researcher's potential to conduct innovative research and for her commitment to research of industry relevance. An academic that has patented once may increase her visibility with industry and satisfy the need for relevance, which has also become an explicit requirement for public funding.

3 DATA AND VARIABLES DESCRIPTION

3.1 *Sample and data collection*

In dealing with academic patent data, it is not enough to look at patent applicants: many inventions originating from university laboratories are in fact owned and applied for by companies that financed research projects or paid for patent use. For this reason, we identify UK academic patents by asking

[6] Thursby and Thursby (2011) have shown empirically that patents help to attract funding from industry).

[7] Prior research has shown that patents are usually associated with groundbreaking, basic research that can also be published in top scientific journals (Murray and Stern, 2007).

inventors directly, rather than depending on patent ownership. In other words, we are able to consider not only patents owned by universities and other public research institutions, but also patents invented by academic researchers that are owned by private organizations.

The procedure takes into account the fact that the number of university patents is underestimated when only patents awarded to universities are counted (Geuna and Nesta, 2006; Lissoni et al., 2008). In fact, it has repeatedly been shown that a large share of academic patents are owned by industry or the inventors themselves. Academic researchers are often engaged in research that leads to a patent, but the university (or the public research centre) does not appear as the patent's applicant[8]. This could be due to private contacts researchers have with firms (Thursby et al., 2009) or because the university is involved in a research project with a firm (Verspagen, 2006).

The methodology used to build the database largely follows what was implemented for the KEINS database (Lissoni et al., 2006; Lissoni et al., 2008). As such, the CID-KEINS database results from two different sources:

- *EP-INV database* produced by Kites (Cespri) - Bocconi University, which contains all EPO applications filed between 1978 and 2002, reclassified by applicant and inventor;
- *Research Assessment Exercise (RAE) 2001 database*, which contains data on individual scientists in British universities and higher education institutions in 2001.

The two sources have been combined by means of name matching (based on surnames and first initials), which resulted in 9,009 potential academic inventors. Then, we searched the web (Google search engine and university

[8] UK universities and their scientists entertain relationships much more similar to ordinary employer-employee ones, which include the employer's control of IPRs over the employee's inventions, and the empoloyee's duty of disclosure of his inventions to the employer (the only possible exception being Cambridge, where a social norm similar to the professor's privilege was held until recently).

websites) in order to collect email addresses and delete false matches by looking at the non-correspondence between professors' and inventors' first names. We confirmed inventor status with an extensive follow-up e-mail survey[9], during which we also asked academic researchers to provide their CVs.

The final sample includes 622 British academic inventors, who are responsible for 1622 patents from 1980 to 2002. 1376 patents were applied for while the inventor was working in a university; the remaining 246 patents were filed while she was working in a company prior to moving to university. The most represented universities (see Table A1 in Appendix A) are Oxford University (with 53 inventors), Cambridge University (47) and Imperial College (41).

Of course, the sample is far from being the entire population of UK academic inventors. In addition, because the sample is based on the patenting activity of professors active in 2001, the academic patent intensity is underestimated, as it does not take into account inventors, whose career ended before 2001. The sample represents 2.1% of university researchers active in 2001 as listed in the RAE 2001, which is similar to the academic patenting intensity found in other European countries, which ranges from 3.9% in France to 4.2% in Sweden (see Lissoni et al., 2008 for a complete picture of academic patenting activity in Italy, France and Sweden).

Table 1 shows the distribution of academic inventors (the ratio of academic inventors over all researchers) across disciplines in the UK and in other European countries (Lissoni et al., 2008): the distribution is similar to that of other European countries, but agriculture and veterinary and engineering are the disciplines most represented in the sample. On the other hand, academic inventors are relatively underrepresented in physics, where the intensity is only around 0.3%.

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[9] 5,005 potential academic inventors resulted from the web search; 2804 emails were found. We received 1079 answers, 616 confirming the inventor status. Table A1 and A2 in Appendix A control for potential sample bias and we find no significant differences in terms of university affiliations (Table A1) and disciplines (Table A2) distributions between academic inventors and non-respondents.

TABLE 1 ABOUT HERE

As a next step, we collect personal information from CVs or through web-searches. This includes gender, PhD institution, PhD year, discipline, and publications published at the start of career (up to three years after the PhD)[10]. Due to missing information on PhD institutions for 66 scientists, our sample was reduced to 555 researchers[11]. On average scientists in the sample gain their PhD in 1981, in 8% of cases from a non UK institution. Data on internal TTOs are retrieved from the Higher Education-Business and Community Interaction Survey (HE-BCI Survey)[12] 2009. UK institutions opened their internal TTOs around 1996, but great heterogeneity appears in the data. Around 18% of universities opened an internal TTO before 1990, and yet only 30% before 1995[13]. However, in the second half of the 1990's there has been an "explosion" of TTO foundation and in 2001 more than 80% of universities had at least an internal department to manage consultancies and external interactions.

3.2 *Main variables*

Our main objective is to explain how inventors may become highly productive. We rely on three different measures of patent productivity. We consider the

[10] Scientific publications and related citations are manually downloaded from *ISI- Web of Knowledge* up to 3 years after the year of the PhD (maximum of 7 years since year of first publication, which can be as early as 20 years before PhD award. 7 years should account for the 4 year PhD period and the first 3 years after the PhD).
[11] We also drop an outlier whose scientific productivity was almost twice that of the second most productive scientist.
[12] http://www.hefce.ac.uk/pubs/hefce/2011/11_25/
[13] The first universities to open internal departments to manage consultancy links and other external interactions are Loughborough University (1969), Cambridge University (1970), University of Surrey (formerly Battersea College of Technology, London, 1970), and University of Leeds (1971).

total number of patents applied for by researchers regardless of whether their workplace is a university or a company (TOTAL PATENTS), then we consider only patents applied for while the scientist was working in a university (TOTAL ACADEMIC PATENTS), and finally we consider the patent quality by weighting the sum of the academic patent applications by the number of citations (TOTAL ACADEMIC CITATIONS) they received in the first five years after the filing (excluding self-citations).

With regard to the distribution of total academic patents, almost half of the inventors have applied for just one patent, 25% of inventors for more than 3 patents, and 10% for more than 6 patents. The skewedness with a long right tail confirms the well-known picture that the number of highly productive scientists is a relatively small fraction of all scientists (Lotka, 1926).

FIGURE 1 ABOUT HERE

We consider three sets of factors, which might be correlated with the inventors' profiles: the *signalling effect*, the *training effect* and *intrinsic scientific ability*.

As discussed in the previous section, initial success in patenting activity may encourage continuous involvement, both for reasons of affirming an academic's research efforts and for economic reasons as academics that have successfully patented in the past might have access to additional funding and support. The *signalling effect* is based on the hypothesis that researchers whose first patent was granted and received a large number of citations are successfully signalling their ability to potential sponsors and are thus more likely to remain active inventors. We consider a patent as successful if it was granted (GRANTED) and if it received a great number of forward citations (FORW_CIT is defined as the number of forward citations in the 5 years after the priority date, excluding self-citations at the inventor level). Positive signs are expected for both measures.

The *training effect* refers to the social interaction during early career stages: many authors have underlined that institutions (e.g. universities, laboratories, hospital schools), by transmitting a particular set of behaviours, skills and norms, are able to shape individuals sharing the same environment with similar attitudes. Following Bercovitz and Feldman (2008: 73), "individuals trained at institutions where participation in technology transfer was actively practiced will be more likely to adopt these practices in their own careers". As discussed in the Introduction, scientists that trained at universities, which had already realized technology transfer policies at the time of their PhD were more likely to socialize with patent-oriented norms and routines, which in turn made them more likely to disclose inventions than their colleagues that had trained at institutions without a TTO. From this we can conclude that the presence of a TTO may affect considerably the practices and behaviours of researchers during their whole careers. TTO_EFFECT captures this effect, being a dummy, which is equal to one if the inventor was at a university that had already established a TTO at the time of her PhD. A positive relationship is expected.

Then, the impact of commercial socialisation in industry on patenting is investigated by considering whether researchers have been involved in patenting before joining academia. ACADEMIC is a dummy that refers to the inventor's employment status at the time of her first patent and equals one if she was working in a university and zero otherwise. A negative sign is expected to the extent that researchers that have been involved in patenting before joining academia are more likely to be familiar with the patenting process and are benefitting from knowledge flows (Agrawal et al., 2006, Dietz and Bozeman, 2005).

In a similar way, we also take into account the characteristics of the first patent applicant in terms of type (university or firms) and size (new, small, medium and big firms)[14]. There is no perfect correspondence between inventor's employment status at the time of her first patent and patent ownership. Patents, which are invented by the professors while they were in academia and owned by universities represent only the 42% of cases (ACADEMIC=1 & UNIVERSITY=1)[15]. We thus expect that if an academic patent is owned by a big company, inventors have more chance to keep in touch with industrial needs and in turn to have more opportunity to patent again.

The peer effect could be considered as an aspect of the broader concept of *training effect*. We considered COINVENTOR'S EXPERIENCE, a proxy of the influence exerted by co-inventors as measured by their patenting experience. In a similar way, Stuart and Ding (2006) showed that proximity to co-authors and colleagues that are active entrepreneurs[16] influences an individual's propensity to move to entrepreneurship to the extent that scientists with experience in such commercial activities are "able to provide advice on practical matters, including how to navigate the university's technology transfer office" (Stuart and Ding 2006: 105).

We also considered the type of institution that granted the PhD degree to account for some differences in organisational structure. We consider four types of universities: (1) Russell Group universities, a group of research intensive universities with a large focus on sciences, (2) Technical universities

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[14] We do not have information on the size of the assignee. We classify the applicant size according to their recent patenting experience: for each patent we calculated the total patent applications of the applicant in the previous two years. Then we categorized the applicant type and size as follow: UNIVERSITY (if one of the applicants was a university), NEW FIRM (for applicant without patent applications before), SMALL FIRM (for applicant with a number of patent applications between 1 and 38), MEDIUM FIRM (39,217) and BIG FIRM (more than 217). The thresholds have been chosen according to the distribution.

[15] In three cases patents are invented by professors while they were working in the private sector, before joining academia, but owned by a university (ACADEMIC=0 & UNIVERSITY=1): we explain this with cases of university-spinoffs.

[16] They considered as entrepreneurs those scientists that founded and were elected as scientific advisors of biotech firms that filed an IPO prospectus (form S1 or SB2) with the U.S. Securities and Exchange Commission (SEC).

that transformed from technical colleges to universities in the 1960s and have a strong focus on engineering and applied sciences, (3) former polytechnics, a group of universities that emerged from teaching colleges in 1992, and (4) other comprehensive universities with small science and engineering departments.

To consider a researcher's scientific ability we look at the quality of research published during the early stages of her scientific career, usually stemming from PhD research. This EARLY SCIENTIFIC PRODUCTIVITY is measured as the average number of citations received in the first five years of publications published in the first seven years of a scientist's career and up to 3 years after the award of the PhD. If patenting and publishing activities are correlated then we expect a positive relationship of these variables with being a persistent inventor[17].

Finally, other variables are considered as *controls*. Concerning the inventors' characteristics, age is measured as scientific age and represents the years since PhD or years since the first publication, whichever was earlier. We make this choice since in some disciplines, such as medical sciences, the research career starts long before the year of the PhD. The average academic inventor in our sample starts her scientific career in 1980. AGE is expected to be positively correlated with patenting productivity as older scientists simply have more years to *produce* patents. However, because we considered EPO patent applications, and the EPO was founded in 1978, older scientists reach their research and patenting productivity peak before the establishment of the European Patent Office. We control for this by inserting AGE squared, which is expected to have a negative sign.

Moreover, we control for a delayed patenting start by inserting the LATE START variable, which is the difference between the year of the first patent

[17] Many scholars find that academic inventors are also very prolific authors as their engagement in patenting activity positively affects publishing activity (Azoulay et al., 2007; Breschi et al., 2005; Calderini et al., 2007).

and the year of the PhD. This measure takes into account that scientists starting their patenting activity later both have less time available to patent after the first one and do not benefit from the PhD environment influences, which we consider as important for shaping researchers' patenting profiles.

FEMALE is a dummy that controls for sex differences in patenting productivity[18].

Moreover, we consider dummy variables for different scientific disciplines as the propensity to patent differs across sectors (Orsenigo and Sterzi 2010). We aggregated units of assessments in five broad disciplines (see Table A3 in Appendix A): *Medicine*, *Biological Sciences*, *Chemistry*, *Physics* and *Engineering Sciences & Electronics*. Because effectiveness and use of patents vary by sector, we expect scientists working in disciplines closer to sectors where patent protection is deemed to be essential for further development and commercialization of the inventions - such as Chemical and Pharmaceutical sectors (Mansfield, 1986) - to have more patent applications.

The variable definitions and their relevant summary statistics are shown in Table 2.

TABLE 2 ABOUT HERE

4 EMPIRICS: METHODOLOGY AND RESULTS

4.1 *Method*

In estimating the patenting productivity, we refer to the sum of patent applications and total citations received. In particular, we have three sets of dependent variables: the number of patent applications, the number of

[18] See Cole and Zuckerman (1984) and Xie and Shauman (1999) for analysis on sex differences at the scientific productivity level.

academic patent applications (i.e. applications filed while the scientist was working in academia), and the total number of citations received by the academic patent applications in the first five years following the priority year without considering the first patent application to avoid endogeneity issues. These measures are non-negative integers and challenge the use of linear regression models such as OLS. Moreover, as in the case of scientific productivity, patenting productivity is also highly skewed. In these cases, general count-data models have been proved to be advantageous over OLS. Due to the over-dispersion of the data, the best alternative solution is a negative binomial model (Cameron and Trivedi 1986, 1990).

4.2 *Baseline results*

We illustrate the results in Table 3. Columns 1-2 present the estimates for the total academic patent application case; columns 3-4 the estimates for the total academic applications; columns 5-6 for the total academic applications weighted by forward citations. All three measures return similar results and indicate that *signalling* and *training* exert an important effect on invention persistency.

TABLE 3 ABOUT HERE

The *training* effect plays an important role for total patent applications (column 1) and total academic patents weighted by citations (column 5), but its effect slightly diminishes for the simple count of academic patents (column 3). In particular, inventors that trained at a university that had already established a TTO at the time of her PhD (TTO_EFFECT) apply for more patents. In terms of marginal effects, a median inventor training at a university that had already established a TTO at the time of their PhD is associated with 0.36 additional patent applications (0.26 academic patent applications, though significant only at 85%) with respect to inventors that trained in a university without TTO.

Interestingly, inventors, who applied for their first patent while working in a university (ACADEMIC) have fewer patent applications overall, but this effect vanishes when we consider only academic patent applications, meaning that scientists that have been involved in patenting before joining academia produce more patents than their peers, but also that they do not patent more once they enter academia. However, as soon as we consider the number of citations of these academic patent applications, the effect becomes significant and strongly negative. Hence, researchers with a history in industry receive more citations even after joining academia than their purely academic peers.

Finally, individuals that started to patent in a network of highly productive inventors have a higher propensity to patent persistently: CO-INVENTOR EXPERIENCE is found to be positively correlated with the number of subsequent patent applications, but not with their citations.

Concerning the *signalling effect*, we find that the success of the first patent matters for the overall patenting productivity. Both measures of patent quality (FORW_CIT and GRANTED) are highly positive and significant in all the specifications. In particular, a median inventor, whose first patent has been granted is associated with 1 additional patent application with respect to a median inventor, whose first patent has *not* been granted.

The organisation type of the PhD awarding institution shows that researchers that trained either at institutions with smaller science and technology faculties or at technical universities that transformed from technical colleges to universities in the 1960s generate fewer patents and are less cited than researchers at the other types of institutions (i.e. Russel group and foreign institutions).

Contrary to our expectations, quality of research published during the early stages of one's career (EARLY SCIENTIFIC QUALITY), usually stemming from PhD research, is not found to be an important predictor for patenting persistence.

Finally, with regard to control variables, first we find, as expected, a positive effect of AGE in its linear component and a negative effect for the squared term. Older scientists are associated with more patent applications and citations, but *too old* scientists reached their scientific (and patenting) peak *too early*, that is before the establishment of the EPO. This intuition is confirmed in the robustness check section where, when considering only younger scientists, we do not find a significant effect of age-squared.

Moreover, the LATE START variable, which reflects the difference between the year of the first patent and the year of the career start, as expected, is found to be negative and significant.

Gender does not seem to have an impact as the female dummy is positive but not significant.

Ownership of the first patent matters to the extent that scientists who applied for their first patent with an inexperienced firm (NEW FIRMS) - either new firms or spin-offs - or a university (UNIVERSITIES) are associated with fewer patent applications. However, these differences disappear when considering academic patent applications and their citations.

Finally, disciplines do not matter: scientists in *Pharmaceutical* and *Chemical* fields are not associated with more patent applications and citations. However, sectoral differences are more evident once controlling for the first patent technological class instead of professor's discipline: estimate results (not shown but available from the authors upon request) show that scientists patenting in the pharmaceutical and chemical sectors are expected to produce more patents on average.

4.2 ***Robustness check***

Cohorts of scientists

Because the sample consists of different cohorts of scientists, it is also characterized by high individual heterogeneity. In fact, although all scientists considered in the empirical sections are still active in service in 2001, there is a great variance in terms of age. People, who obtained their PhD degree before 1980 eventually behave differently from those, who obtained it in 1980 or even fifteen years after: different technological capabilities, social norms and propensity to patents might play differently over time.

To check for this eventuality, we consider the same models discussed above for a restricted number of scientists according to their cohorts: in columns 1-3 only scientists that started their scientific careers[19] after 1982 are considered, in columns 4-6 those who started after 1986.

All estimate coefficients are in general very similar to that of the baseline and confirms the role of training and signalling on patenting persistence. However, and contrary to the previous analysis, academic scientists whose first patent had been applied for by a university (UNIVERSITY) are associated with more patent applications, a result closely linked to the growing importance of patenting within universities.

5. DISCUSSION AND CONCLUSION

[19] The career starts with the year of the first publication or the year of the PhD, whichever is earlier.

As argued in previous literature, star scientists are very important for the advancement of knowledge and exert a positive effect on their co-workers. Using a sample of 555 UK academic inventors from the CID-KEINS database this paper attempts to characterise persistent academic inventors and to identify those factors that might explain persistent participation in the innovation process. We compare inventors that show different levels of patenting success and find evidence for two important mechanisms at work: *signalling effect* and *training effect*.

Our main results indicate that the success of the first patent application is a good predictor for the propensity to invent persistently. Researchers whose first application was granted and received a large number of citations are more likely to apply for more patents due to some *signalling effect*. It has been shown that academic inventors attract more funding, especially from industry, and hence have access to the necessary support needed for continuous commercial involvement (Link et al., 2007; Meissner, 2011; Owen-Smith and Powell, 2001). In addition, initial success in patenting may encourage continuous involvement; academics that succeed with their first application feel encouraged in their research and dissemination strategy. Researchers that experience failure, on the other hand, may find patenting too costly and little rewarding and abstain in future. However, a note of caution is due. One concern is the possible omitted variable problem, which might make the success of the first patent variables endogenous. It is possible that we are not able to control for all the unobserved heterogeneity at the individual level, which may explain at the same time both the first patents success and the patenting productivity throughout the scientific career. To test the importance of the first patent application and to give support for our signalling hypothesis we can regress the signalling effect on the researcher's scientific productivity. If researchers have an incentive to signal for attracting more funds for scientific research then we should see a positive effect of first patent success on scientific publications. Table A4 in Appendix B displays the results of such an exercise and shows that indeed the number of citations received by the first patent application has a positive significant impact on the quality of a researcher's publications[20], thus confirming our signalling hypothesis.

We further find evidence for a positive *training effect*. Researchers who undertook their PhD studies at a university that had already implemented mechanisms to support technology transfer at the time of their PhD have a higher propensity to patent persistently throughout their career. This supports findings by Bercovitz and Feldman (2008), who showed that social imprinting at PhD level, is more important than local peer effects. A supportive technology transfer office, even if not directly involved in the commercialisation of an invention, can help create an environment that rewards commercial activity and thus encourages patenting. We also find evidence for a positive effect of commercial socialisation in industry. Researchers that first appeared as inventors on a patent while working for industry do not generate more patents than their colleagues once they join academia, however, they produce patents that are more cited and hence of higher quality. These industry-trained researchers may thus be better able to recognise inventions with high commercial potential, making them more successful. Also, they might be able to benefit from their links to industry, which generates stronger knowledge flows.

Finally, we find no correlation between early career scientific output and patenting. Previous research has shown that inventors publish more than their non-patenting peers (Azoulay et al., 2007; Breschi et al., 2005; Calderini et al., 2007). We show that the most successful inventors do not publish more than single inventors at the start of their career. However, in Appendix B we show that patent signalling increases not only the number of subsequent patents but also the quality of scientific research output.

[20] Scientific publications were taken from the research output details submitted to the RAE 2001 and represent their top 4 publications during the period 1996 to 2000. These were then weighted by the impact factor of the journal in which they appear. The measure should hence be a good indicator of a researchers scientific quality during the 1996-2001 period.

In terms of policy implications, we conclude that an environment that rewards patenting is particularly important to encourage patentable research. With the introduction of university commercialisation units (TTOs) across the UK, and the increasing emphasis on commercialisation already at PhD level at most universities, we should see more inventors that are persistent in future. Further, links with industry can foster knowledge diffusion, as we observed in a high number of patent citations, to the extent that professors and departments with strong connections with industry are able to access further financial resources and ideas (Mansfield, 1995, 1998; Siegel et al., 2003).

This paper has added some important evidence on the characteristics of academic inventors. Further data in panel structure is needed to address potential endogeneity and to better control for intrinsic ability of researchers.

Appendix A: Controlling for Potential Sample Bias

TABLES A1, A2, A3 HERE

Appendix B: Regressing Signalling Effect on Scientific Quality

To test the signalling hypothesis we consider scientific quality instead of patenting productivity as dependent variable. Scientific publications were taken from the research output details submitted to the RAE 2001 and represent a researcher's top 4 publications during the period 1996 to 2000. These were then weighted by the ISI Journal Impact Factor of the journal in which they appear. The journal impact factor represents the average number of citations received by articles published in the journal in the 3 years following their publication.

We use three different measures in the regression. The first is the maximum impact factor of articles submitted to the RAE (MAX JIF). The second measure is the sum of the impact factors of all publications submitted (SUM JIF). The third measure is the average impact factor per publication to account for researchers that have submitted fewer than 4 publications (AVG JIF). The average quality of an inventor's publication is 4.66.

In table A4 we report the results of the regressions, first for the total sample and then for a reduced sample of academics that filed their first patent application before 1996, to avoid simultaneity. The results show that the quality of the first patent (FORW_CIT) is always significant and positive, confirming our signalling hypothesis. Additionally, EARLY SCIENTIFIC QUALITY is significant and positive giving evidence for a Matthew Effect (Merton, 1968). TTO and industry experience have no significant impact on publications.

TABLE A4 ABOUT HERE

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Tables

Table 1. Academic inventors as percentage of total professors, by disciplines

	UK	*Sweden*	*Italy*	*France*
Agricultural and veterinary	3.5%	*3.9%*	*1.8%*	*n.a.*
Biological sciences	1.5%	*8.1%*	*4.2%*	*4.2%*
Chemical sciences	2.1%	*10.2%*	*10.8%*	*8.6%*
Earth sciences	0.3%	*0.0%*	*0.3%*	*0.1%*
Engineering	3.1%	*4.5%*	*5.5%*	*5.1%*
Maths and info.sciences	1.4%	*0.9%*	*1.6%*	*0.6%*
Medical sciences	2.1%	*4.3%*	*1.9%*	*4.0%*
Physical sciences	0.3%	*5.6%*	*2.7%*	*2.4%*
All disciplines	2.1%	*4.2%*	*3.9%*	*3.9%*

* Sweden, Italy and France taken from Lissoni et al. (2008)

Table 2. Definitions and summary statistics

	Definition	N of obs.	Mean	S.D.	Min	Max
Dependent variabile						
Total patents	Total number of patent applications filed by the scientist.	555	3.02	3.96	1	31
Total academic patents	Total number of patent applications filed while scientist was working in university.	555	2.85	3.79	1	31
Total academic citations	Sum of patent applications weighted by number of citations received in the first 5 years after filing. Self-citations at the inventor level are excluded. First patent is excluded.	555	3.74	11.11	0	99
Scientist's characteristics						
Age	2001 minus year of PhD or first publication whichever was earlier	555	21.63	9.18	3	52
Female	Dummy=1 if woman	555	0.08	0.26	0	1
Late start	FIRST PATENT YEAR - PHD YEAR	555	15.04	8.63	-4	45
TTO_EFFECT	Dummy = 1 if the inventor was at a university with a TTO during her PhD	555	0.21	0.40	0	1
Early Scientific quality	Average number of citations during the first 5 years to articles published in the first 3-7 years of career	555	12.59	17.68	0	186
PhD institutions type						
Foreign PhD institution	Foreign institution	555	0.08	0.27	0	1
Russell Group	Russell Group (collaboration of twenty research intensive UK universities that together receive two-thirds of research grant and contract funding in the United Kingdom).	555	0.70	0.47	0	1
Other institutions	Other comprehensive universities	555	0.14	0.35	0	1
Technical universities	Universities granted Royal Charter in the 1960s following the Robbins Report on higher education, and developing out of technical colleges	555	0.08	0.28	0	1
Former polytechnics	1992 universities granted Royal Charter in the 1990s and developing out of polytechnics (non-research institutions)	555	0.03	0.18	0	1
Medicine	Discipline: Aggregated scientists' fields from unit of assessments (source: RAE 2001)	555	0.27	0.44	0	1
Biology		555	0.17	0.38	0	1
Pharma & Chemistry		555	0.15	0.36	0	1
Physics & Maths		555	0.08	0.27	0	1
Engineering		555	0.32	0.47	0	1
First patent characteristics						
FORW_CIT	Number of citations received in first 5 years after filing. Self-citations at the inventor level are excluded	555	1.99	3.45	0	33
GRANTED	Dummy =1 if focal patent was granted	555	0.66	0.47	0	1
Co-inventors'experience	(Max) number of patent applied for by scientist's co-inventors before the focal patent.	555	1.75	8.70	0	185
Applicant size:						
Big firm	Applicant with more than 217 patent applications in the two years prior to the focal patent	555	0.05	0.21	0	1
Medium firm	Applicant with fewer than 218 patent applications but more than 38 in the two years prior to the focal patent	555	0.17	0.38	0	1
New firm	Applicant without any patent in the two years prior to the focal patent	555	0.13	0.34	0	1
Small firm	Applicant with fewer than 39 patent applications in the two years prior to the focal patent	555	0.22	0.41	0	1
University	At least one applicant was a university	555	0.43	0.50	0	1
Academic	Dummy=1 if focal patent was filed while scientist was working in academia; =0 if she worked in a company	555	0.95	0.22	0	1

Table 3. Productivity results (Negative Binomial Regression Estimates)

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent variable	Total patents	Total patents	Total academic patents	Total academic patents	Total citations (to academic patents)	Total citations (to academic patents)
AGE	0.14***	0.14***	0.13***	0.13***	0.39***	0.40***
	(0.016)	(0.015)	(0.016)	(0.016)	(0.044)	(0.045)
AGE ^2	-0.0010***	-0.0010***	-0.00099***	-0.0010***	-0.0042***	-0.0043***
	(0.00030)	(0.00031)	(0.00031)	(0.00031)	(0.00082)	(0.00084)
FEMALE	0.036	0.036	0.062	0.061	0.25	0.19
	(0.10)	(0.10)	(0.10)	(0.10)	(0.26)	(0.26)
LATE START	-0.081***	-0.081***	-0.080***	-0.080***	-0.18***	-0.18***
	(0.0087)	(0.0085)	(0.0087)	(0.0085)	(0.020)	(0.019)
FORW_CIT	0.058***	0.049***	0.057***	0.046**	0.17***	0.13***
	(0.011)	(0.018)	(0.011)	(0.018)	(0.022)	(0.036)
GRANTED	0.42***	0.44***	0.51***	0.52***	1.31***	1.25***
	(0.062)	(0.063)	(0.060)	(0.062)	(0.25)	(0.25)
ACADEMIC	-0.54***	-0.56***	0.13	0.12	-1.43***	-1.45***
	(0.14)	(0.15)	(0.19)	(0.19)	(0.42)	(0.47)
EARLY SCI. QUALITY (ESQ)	0.00048	0.00068	0.00063	0.00072	0.0030	-0.0060
	(0.0016)	(0.0020)	(0.0017)	(0.0020)	(0.0053)	(0.0063)
CO-INVENTORS'EXPERIENCE	0.0024**	0.0019*	0.0027**	0.0020*	-0.0013	-0.0017
	(0.0012)	(0.0011)	(0.0012)	(0.0011)	(0.018)	(0.018)
TTO_EFFECT	0.15*	0.19**	0.11	0.15*	0.64**	0.71***
	(0.087)	(0.087)	(0.089)	(0.090)	(0.26)	(0.25)
PhD Institution.						
Refe. case: Russell Group						
Foreign PhD	-0.15	-0.15	-0.18	-0.17	0.16	0.034
	(0.13)	(0.13)	(0.13)	(0.13)	(0.43)	(0.45)
Other institutions	-0.32***	-0.35***	-0.38***	-0.40***	-0.69***	-0.60**
	(0.086)	(0.091)	(0.089)	(0.095)	(0.26)	(0.26)
Technical universities	-0.18**	-0.17*	-0.22**	-0.21**	0.023	0.023
	(0.092)	(0.094)	(0.091)	(0.092)	(0.42)	(0.41)
Former polytechnics	0.064	0.082	0.022	0.056	-0.13	-0.049
	(0.21)	(0.21)	(0.21)	(0.21)	(0.45)	(0.45)
Reference case: BIG FIRM						
NEW FIRM	-0.33*	-0.31*	-0.27	-0.26	0.015	0.081
	(0.18)	(0.17)	(0.19)	(0.19)	(0.41)	(0.41)
SMALL FIRM	-0.30*	-0.26	-0.24	-0.20	-0.53	-0.52
	(0.16)	(0.16)	(0.18)	(0.18)	(0.35)	(0.36)
MEDIUM FIRM	-0.24	-0.25	-0.21	-0.22	-0.060	-0.090
	(0.17)	(0.16)	(0.18)	(0.18)	(0.36)	(0.38)
UNIVERSITY	-0.36**	-0.36**	-0.32*	-0.32*	-0.48	-0.50
	(0.16)	(0.16)	(0.17)	(0.17)	(0.34)	(0.35)
Reference: medical field						
Biology	0.100	0.12	0.086	0.091	-0.069	-0.87**
	(0.10)	(0.13)	(0.10)	(0.13)	(0.24)	(0.44)
Pharma & Chemical	0.18	0.23	0.18	0.24	0.64**	0.63
	(0.12)	(0.16)	(0.12)	(0.16)	(0.27)	(0.44)
Physics	-0.056	-0.076	-0.0066	-0.11	-0.46	-0.94**
	(0.13)	(0.18)	(0.13)	(0.19)	(0.40)	(0.41)
Engineering	0.042	-0.15	0.037	-0.15	0.13	-0.27
	(0.10)	(0.11)	(0.100)	(0.11)	(0.26)	(0.33)
Biology*ESQ		-0.0027		-0.0026		0.018*
		(0.0032)		(0.0032)		(0.011)
Pharma&Chemical*ESQ		0.0016		0.00070		0.0028
		(0.0064)		(0.0064)		(0.021)
Physics*ESQ		-0.0043		0.0033		0.024
		(0.0074)		(0.0087)		(0.023)
Engineering*ESQ		0.022***		0.019**		0.0027
		(0.0085)		(0.0082)		(0.039)
Biology*FirstPatentQuality		0.012		0.016		0.14
		(0.030)		(0.031)		(0.089)
Pharma&Chemical*FirstPatentQuality		-0.019		-0.017		-0.019
		(0.028)		(0.028)		(0.062)
Physics*FirstPatentQuality		0.027		0.024		0.064
		(0.021)		(0.021)		(0.047)
Engineering*FirstPatentQuality		0.054		0.057		0.12
		(0.037)		(0.036)		(0.082)
Constant	0.076	0.077	-0.62**	-0.63**	-3.26***	-3.01***
	(0.24)	(0.25)	(0.27)	(0.28)	(0.70)	(0.73)
lnalpha	-1.75***	-1.83***	-1.77***	-1.84***	0.96***	0.93***
	(0.15)	(0.15)	(0.15)	(0.15)	(0.11)	(0.11)
McFaddan's Adj R2	0.171	0.176	0.164	0.169	0.139	0.143
Log pseudolikelihood	-1019.9372	-1013.3707	-1001.7208	-995.77036	-852.55514	-848.65444
Observations	555	555	555	555	555	555

In columns 5 and 6 citations to the first patent are excluded. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4. Robustness check. Cohorts of scientists.

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent variable	Total patents	Total academic patents	Total citations	Total patents	Total academic patents	Total citations
	(PHD after 1982)	*(PHD after 1982)*	*(PHD after 1982)*	*(PHD after 1986)*	*(PHD after 1986)*	*(PHD after 1986)*
AGE	0.22***	0.23***	1.08***	0.28***	0.27**	1.38***
	(0.069)	(0.072)	(0.28)	(0.10)	(0.12)	(0.50)
AGE ^2	-0.0046*	-0.0052*	-0.027***	-0.0075	-0.0066	-0.045*
	(0.0027)	(0.0028)	(0.010)	(0.0059)	(0.0065)	(0.024)
FEMALE	0.048	0.076	0.46	-0.12	-0.076	0.82
	(0.10)	(0.11)	(0.38)	(0.16)	(0.16)	(0.55)
LATE START	-0.071***	-0.074***	-0.22***	-0.099***	-0.11***	-0.22***
	(0.012)	(0.013)	(0.037)	(0.021)	(0.022)	(0.053)
FIRST PATENT QUALITY	0.056***	0.055***	0.22***	0.061***	0.057***	0.24***
	(0.017)	(0.016)	(0.036)	(0.017)	(0.017)	(0.061)
GRANTED	0.35***	0.38***	1.21***	0.25***	0.27***	1.13**
	(0.077)	(0.077)	(0.42)	(0.081)	(0.088)	(0.53)
ACADEMIC	-0.59***	-0.18	-2.45***	-0.36*	0.23	-1.65***
	(0.14)	(0.19)	(0.46)	(0.21)	(0.23)	(0.55)
EARLY SCIENT. QUALITY (ESQ)	0.00025	0.00016	0.0044	-0.00033	0.00032	-0.0067
	(0.0019)	(0.0019)	(0.0073)	(0.0021)	(0.0023)	(0.0088)
CO-INVENTORS'EXPERIENCE	0.017	0.013	0.030	0.020	0.017	0.031
	(0.013)	(0.013)	(0.029)	(0.015)	(0.015)	(0.032)
TTO_EFFECT	0.21**	0.22**	0.94***	0.058	0.045	1.60***
	(0.10)	(0.11)	(0.35)	(0.11)	(0.11)	(0.52)
PhD Institution. Refe. case: Russell Group						
insttype_phd==0	0.087	0.11	0.42	0.017	0.034	-0.50
	(0.14)	(0.14)	(0.61)	(0.15)	(0.15)	(0.89)
insttype_phd==2	-0.15	-0.14	-0.18	-0.17	-0.20	0.36
	(0.13)	(0.13)	(0.43)	(0.17)	(0.18)	(0.42)
insttype_phd==3	-0.079	-0.13	0.057	-0.075	-0.12	0.31
	(0.13)	(0.13)	(0.74)	(0.15)	(0.16)	(0.69)
insttype_phd==4	-0.17	-0.17	-0.34	-0.40**	-0.42**	-0.21
	(0.25)	(0.25)	(0.66)	(0.19)	(0.19)	(0.90)
Reference case: BIG FIRM						
NEW FIRM	0.21	0.44**	1.25**	-0.20	0.13	0.60
	(0.22)	(0.19)	(0.52)	(0.24)	(0.23)	(0.67)
SMALL FIRM	0.19	0.40**	0.32	0.12	0.33	-0.66
	(0.19)	(0.17)	(0.51)	(0.21)	(0.22)	(0.69)
MEDIUM FIRM	0.13	0.34**	0.44	-0.11	0.13	-1.35**
	(0.18)	(0.14)	(0.49)	(0.21)	(0.20)	(0.60)
UNIVERSITY	0.23	0.43***	0.89*	0.16	0.38*	0.068
	(0.18)	(0.14)	(0.47)	(0.21)	(0.21)	(0.54)
Scientist's discipline (Reference: medicine)						
Biology	-0.088	-0.13	-0.17	0.14	0.052	-0.45
	(0.098)	(0.10)	(0.37)	(0.13)	(0.14)	(0.52)
Pharma & Chemical	-0.12	-0.15	0.48	-0.071	-0.13	1.35
	(0.15)	(0.15)	(0.53)	(0.23)	(0.24)	(0.83)
Physics	-0.031	-0.0096	-1.31***	0.30*	0.29*	-0.82
	(0.13)	(0.13)	(0.45)	(0.17)	(0.17)	(0.85)
Engineering	0.15	0.15	0.56	0.20	0.20	0.58
	(0.13)	(0.12)	(0.35)	(0.15)	(0.15)	(0.37)
	-0.87*	-1.62***	-8.45***	-1.02**	-1.77***	-9.57***
Constant	(0.48)	(0.46)	(1.78)	(0.48)	(0.55)	(2.69)
	-12.7	-5.58	0.55***	-16.5***	-17.0***	0.28
lnalpha	(48.1)	(7.97)	(0.20)	(0.39)	(0.25)	(0.33)
	(2.70)	(3.94)	(0.21)	(0.71)	(0.21)	(0.33)
McFaddan's Adj R2	0.162	0.147	0.205	0.179	0.160	0.270
Log pseudolikelihood	-349.04886	-345.45654	-258.82787	-198.18003	-194.95067	-129.90983
Observations	238	238	238	143	143	143

In columns 3 and 6 citations to the first patent are excluded. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A1. Top 10 universities: sample vs. non-respondents

	# of inventors	Freq. (%)	# of non-respondents	Freq. (%)
University of Oxford	53	8.52	127	5.78
University of Cambridge	47	7.56	122	5.55
Imperial College	41	6.59	105	4.78
University College London	29	4.66	86	3.91
University of Nottingham	26	4.18	58	2.64
University of Sheffield	25	4.02	57	2.59
University of Bristol	21	3.38	62	2.82
University of Manchester	20	3.22	48	2.18
King's College London	17	2.73	55	2.50
University of Southampton	17	2.73	58	2.64
Queen Mary, University of London	16	2.57	33	1.50
University of Strathclyde	16	2.57	36	1.64

Table A2. Disciplines: sample vs. non-respondents (%).

Aggregated units	Sample	Non respondents
Medicine	27.33	28.24
Biological Sciences	16.40	17.11
Pharma & Chemistry	16.08	14.30
Physics & Maths	7.88	10.98
Eng. Sc. & Electronics	32.33	29.37

Table A3. Disciplines.

Aggregated units	RAE unit of assessment
Medicine	1,2,3,4,5,6,7,10,11
Biological Sciences	14,15,16,17
Pharma & Chemistry	8,9,18
Physics & Maths	19,20,21,22
Eng. Sc. & Electronics	25,26,27,28,29,30,31,32,33

Table A4. Scientific productivity regression.

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent variable	MAX JIF	MAX JIF year_first_patent <1996	SUM JIF	SUM JIF year_first_patent <1996	AVG JIF	AVG JIF year_first_patent <1996
AGE	0.073***	0.062**	0.064***	0.054**	0.055***	0.054**
	(0.022)	(0.029)	(0.019)	(0.025)	(0.019)	(0.026)
AGE ^2	-0.0018***	-0.0021***	- 0.0015***	-0.0019***	-0.0013***	-0.0018***
	(0.00045)	(0.00059)	(0.00039)	(0.00053)	(0.00037)	(0.00055)
FEMALE	-0.15	0.075	-0.12	0.028	-0.20	-0.0043
	(0.17)	(0.27)	(0.14)	(0.21)	(0.13)	(0.19)
LATE START	0.015	0.055***	0.012	0.054***	0.0065	0.043**
	(0.0092)	(0.019)	(0.0081)	(0.019)	(0.0078)	(0.017)
FORW_CIT	0.026***	0.019*	0.024***	0.021**	0.023***	0.018*
	(0.0082)	(0.011)	(0.0070)	(0.010)	(0.0067)	(0.0098)
GRANTED	-0.018	0.24	0.043	0.24*	-0.0051	0.18
	(0.097)	(0.15)	(0.085)	(0.14)	(0.080)	(0.13)
ACADEMIC	-0.082	-0.21	-0.0089	-0.12	-0.100	-0.22
	(0.18)	(0.17)	(0.19)	(0.16)	(0.20)	(0.18)
EARLY SCIENTIFIC QUALITY (ESQ)	0.011***	0.0099**	0.012***	0.011**	0.0099***	0.010**
	(0.0037)	(0.0050)	(0.0037)	(0.0055)	(0.0031)	(0.0047)
CO-INVENTORS'EXPERIENCE	-0.0045*	-0.00082	-0.0038**	-0.0058	-0.0042**	-0.0082
	(0.0025)	(0.0097)	(0.0016)	(0.0088)	(0.0018)	(0.0088)
TTO_EFFECT	0.12	0.028	0.11	-0.035	0.057	-0.035
	(0.14)	(0.21)	(0.12)	(0.20)	(0.098)	(0.17)
PhD Institution. Reference case: Russell Group						
Foreign PhD	0.15	0.0037	0.18	-0.12	0.19	0.022
	(0.14)	(0.19)	(0.13)	(0.17)	(0.12)	(0.16)
Other institutions	-0.16	-0.32**	-0.077	-0.22	-0.043	-0.15
	(0.11)	(0.15)	(0.11)	(0.14)	(0.11)	(0.15)
Technical universities	0.035	-0.30	-0.051	-0.26*	-0.075	-0.28*
	(0.19)	(0.20)	(0.14)	(0.15)	(0.12)	(0.15)
Former polytechnics	-0.55***	-0.54**	-0.49***	-0.38*	-0.41**	-0.28
	(0.19)	(0.25)	(0.16)	(0.21)	(0.19)	(0.26)
Reference case: BIG FIRM						
NEW FIRM	-0.24	-0.27	-0.26	-0.28	-0.13	-0.14
	(0.29)	(0.32)	(0.28)	(0.30)	(0.24)	(0.31)
SMALL FIRM	-0.26	-0.35	-0.33	-0.44	-0.17	-0.20
	(0.30)	(0.33)	(0.28)	(0.31)	(0.26)	(0.33)
MEDIUM FIRM	-0.36	-0.42	-0.38	-0.43	-0.22	-0.21
	(0.29)	(0.33)	(0.27)	(0.31)	(0.24)	(0.32)
UNIVERSITY	-0.33	-0.47	-0.33	-0.55*	-0.13	-0.27
	(0.28)	(0.34)	(0.27)	(0.32)	(0.24)	(0.34)
Reference: medical field						
Biology	0.069	0.070	0.056	-0.0047	0.013	0.014
	(0.11)	(0.17)	(0.099)	(0.16)	(0.094)	(0.16)
Pharma & Chemical	-0.30**	-0.47***	-0.35***	-0.52***	-0.38***	-0.53***
	(0.13)	(0.17)	(0.11)	(0.15)	(0.10)	(0.15)
Physics	-0.60***	-0.90***	-0.74***	-1.07***	-0.74***	-1.01***
	(0.17)	(0.21)	(0.15)	(0.18)	(0.14)	(0.17)
Engineering	-1.68***	-1.67***	-1.67***	-1.76***	-1.64***	-1.63***
	(0.13)	(0.20)	(0.11)	(0.18)	(0.12)	(0.19)
Constant	1.73***	1.87***	2.59***	2.82***	1.40***	1.43***
	(0.37)	(0.49)	(0.35)	(0.46)	(0.31)	(0.42)
lnalpha	-0.73***	-0.79***	-0.76***	-0.72***	-1.34***	-1.29***
	(0.099)	(0.15)	(0.10)	(0.15)	(0.14)	(0.21)
McFadden's Adj R2	0.112	0.122	0.101	0.105	0.146	0.150
Log pseudolikelihood	-1531.6781	-693.8939	- 1954.1288	-894.94231	-1245.499	-1954.1288
Observations	555	254	555	254	555	254

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1