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Publication and patent behaviour of academic researchers: conflicting, reinforcing or merely co-existing?

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Increasing entrepreneurial activity within academia has raised concerns that the amount of publications added to the scientific commons might become reduced or that academic research would become directed exclusively towards the application-oriented needs of industry. In the case of academic inventions, the potential conflict between public and private oriented considerations seems most salient. With this contribution, we examine whether the publication behaviour of academic inventors (at K.U.Leuven) differs from their colleagues (non-inventors) working within similar fields of research. Our analysis reveals that inventors publish significantly more. Moreover, no empirical evidence was found for the 'skewing problem'. These findings not only suggest the co-existence of both activities; they may actually reinforce one another.
Keywords: Knowledge interactions; University–industry relations, Academic Inventors

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1. Setting the stage: The shift towards Entrepreneurial Universities

Science-industry relationships have received considerable attention over the last decades due to an increasing recognition of the fundamental role of knowledge and innovation in fostering economic growth, technological performance and international competitiveness. Different scholars have described and analyzed the multitude of interactions between different types of actors that play a role in the process of knowledge generation and diffusion (Freeman, 1987, 1994; Lundvall, 1992; Nelson, 1993; Nelson and Rosenberg, 1993; Mowery and Nelson, 1999; Dosi, 2000). In this context, the concept of the 'innovation system' has been advanced as a general framework for designing innovation policies and adequate supportive institutional arrangements (OECD, 1999; European Innovation Scorecard, 2002). Knowledge-generating institutions, like universities and research laboratories, industrial public and private research laboratories (the dominant loci of R&D and innovation in most fields) and more recently, government agencies, are seen as key actors in stimulating and influencing the innovative potential of any society. This renewed interest resulted in new insights into University-Industry interactions during the 1990s (Dasgupta and David, 1994) based on the concepts of (1) scientific networks (Steinmueller, 1994; David, Foray and Steinmueller, 1997; Pavitt, 1997;), (2) strategy and its concomittant structural analysis of industries and competitors (Porter, 1995), (3) evolutionary economic thinking (Nelson, 1995) and (4) a new vision on industry, academia and government interactions as encompassed by the 'Triple Helix' model (Etzkowitz & Leydesdorff, 1997, 1998; Leydesdorff & Etzkowitz, 1996; 1998).

Along similar lines, the concept of 'entrepreneurial universities' (Branscomb, Kodama & Florida, 1999; Etzkowitz, 1998; Etzkowitz, Webster & Healy, 1998) has increasingly been used in relation to the spectrum of evolutions that have taken place in recent years within academia: more involvement in socio-economic development, more emphasis on exploiting research results, correlated with (1) an increase in patent and licensing activities, (2) the institutionalization of spin off activities and (3) managerial and attitudinal changes among academics with respect to collaborative projects with industry. One might therefore speak of a 'second academic revolution' during the 1990s[2], adding entrepreneurial objectives as a third component to the mission of the university (Etzkowitz and Leydesdorff, 2000).

Multiple elements have contributed to the growth of this entrepreneurial phenomenon, which, at least in the US, should be seen as a logical extension of the successful involvement of university research in fields such as space, defence and energy during the 1940s, 50s and 60s[3]. Amongst the explanations offered for this phenomenon, shifts in federal funding (US), as well as changes in the tax treatment of R&D expenditures, have been identified as relevant and important. In addition, in the US, a shift in priorities has been observed during the eighties, favouring R&D that would contribute to American productivity and global competitiveness (Cohen and Noll, 1994).

A crucial dimension in the process of developing academic entrepreneurial capacity relates to the adoption of policy measures regulating intellectual property rights and their related patenting and licensing activities. Well known regulations are the Bayh-Dole Act and the Stevenson-Wydler Act in the US, while in Europe, similar arrangements are becoming more widespread (e.g. the 1998 Decree in Flanders, Belgium and the 2001 German legal changes on the professors' privilege concerning the ownership of their inventions). These new regulations gave universities ownership of intellectual property arising from government-funded research as well as the right to commercialize the results obtained. Those measures have given a significant boost to the adoption or the further development of IPR-related procedures and policies, while contract research conducted at universities has become more and more incorporated into the mission of today's universities (Branscomb et al. 1999; Etzkowitz & Kemelgor, 1998; Van Looy et al, 2003b). At the same time, as Kodama and Branscomb notice, it should be recognized that the economic sectors with the most rapid growth are those closest to the 'science base': microelectronics, software, biotechnology, medicine and new materials. These growth areas are dependent on highly skilled people and they are embedded in the findings of the latest research. Hence, it should come as no surprise that universities and knowledge generating institutions

[2] After research complementing education as an inherent part of university's mission during the 19th century, the so called 'first academic revolution'.

[3] And can even be traced back to efforts and experiences situated in the 19th century (see in this respect for instance Hane, 1999; Kodama & Branscomb 1999, Rosenberg & Nelson, 1994).

find themselves in an advantageous position to contribute to and to participate in the growth of these very industries (Kodama & Branscomb, 1999).

The increased emphasis on knowledge- and technology-transfer across University-Industry institutional boundaries has led to the creation and implementation of a variety of transfer-oriented mechanisms. These include industrial liaison or technology transfer offices, academic spin-offs and joint ventures (whereby universities may even start acting as a shareholder), seed money funds, science parks and business incubators. Those new arrangements all reflect the broader societal role attributed to research institutes. As a 2001 CORDIS report summarized, excellent research institutes can contribute to the overall national innovation capacity in three ways. First, they can provide information and ideas that serve as a basis for the development of new products, processes and services. Second, their pursuit of long-term goals may advance the state of the art in new knowledge areas and may serve as a training ground for highly qualified staff. Finally, the ability of research institutes to forge connections between specific research fields strengthens the broader national and EU scientific knowledge base (CORDIS, 2001).

This whole activity must not, however, be seen as a uni-directional knowledge flow, from universities to industry and society at large, but also as a vehicle for a two-way knowledge and information transfer from the private research sector to universities, and vice versa. The changes taking place in academia cannot be dissociated from the transformations that marked business R&D over the last two decades. These changes imply more competition on international technology markets, accelerated transition from the laboratory to knowledge markets and the need to share increasing research risks and costs, all of which determine a growing need of companies to access externally-generated knowledge and all of which signal 'the decline of technical self-sufficiency' (Fusfeld, 1995). Business R&D has increasingly been faced with the challenge of getting access to external sources of technology and knowledge and to identify trained human resources, new partners and markets. These issues became the major drivers for company involvement in partnerships, alliances, co-operative programs and consortia with universities and government laboratories (Etzkowitz, 1998; Mowery & Nelson, 1999, Tijssen, 2004). At the level of public R&D funding, these evolutions have been further recognized and even institutionalized. The 6th Framework Programme of the EC is an example of this institutionalization. Large public technology initiatives, as they exist for instance in the US, are yet a further illustration of this trend (e.g. the Hydrogen Fuel Initiative in the US).

The combined effects of these drivers and trends account for an overall increase in levels of university-industry cooperation, and it is hard to separate each factor's independent contribution in the shift towards more entrepreneurial research institutions. Moreover, different societies display specific degrees of entrepreneurial behavior and have their own ways of adopting an entrepreneurial stance and culture. However, whether one looks at Europe, the US or Japan, entrepreneurial universities have become a reality that cannot be ignored any longer. Substantiation of this reality can be found in the indicator frames for assessing knowledge-generating institutes, which start to include entrepreneurial oriented indicators more systematically[4] (for a more detailed discussion, see Van Looy et al., 2003a)

2. Entrepreneurial universities: Advantages *and* Concerns

This renewed and increased interest in university-industry linkages has resulted in the identification of advantages as well as concerns. Advantages can be identified in terms of improving industrial innovation, extra university funding opportunities or still, the faster exploitation of new inventions by increased patenting or spin off activity. At the same time, the increasing trend of developing entrepreneurial capabilities in academia gave rise to several concerns related to the role of academia in society (Gibbons, 1999; Kelch, 2002; Martin, 2001, 2002). Indeed, an explicit fear is related to the impact of University-Industry co-operation on university researchers' research agendas (Geuna, 1999; Hane, 1999; Vavakova, 1998) and the conflicts of commitment and interests (Faria, 2002) that occur when faculty members' full-time duties (teaching, research, time with students and service obligations to the university) are affected by activities stemming from involvement in company cooperation – such as consulting activities -, notwithstanding the observation that most universities have formal policies regarding and regulating this issue (ACE, 2001). The main concerns originate from the fundamentally different reward and incentive systems of academic and private sector research,

[4] E.g. the annual overview published by MIT Tech Review, based on figures and analyses conducted by CHI Research and the Association of University Technology Managers.

in terms of (1) the relationship between disclosure versus secrecy and (2) the complementarities and substitution effects between public and private R&D expenditures (Dasgupta and David, 1987, 1994).

In terms of incentive systems, one of the cornerstones of the academic enterprise concerns the publication of research results and the opportunity for open discussions between colleagues. Companies, on the other hand, have a responsibility for and a need to protect the value of their investments. These differences in the incentive systems of public and private research create challenges with regard to the dissemination of information, the nature of the research conducted and the access to research results (Hane, 1999) and is therefore re-opening debates on the norms and values guiding academic science (see for instance, Merton, 1968 a,b; Mitroff, 1974, Mulkay, 1976). For instance, some forms of publication might be delayed or suppressed, because firms may ask universities to keep information (temporarily) confidential. This might reduce the incentive to publish, and run counter the academic norm of open dissemination of scientific knowledge (Blumenthal et al., 1996). Florida and Cohen (1999) referred to this as the 'secrecy problem' in research universities. Empirical evidence has indeed shown an association between industry support for research and restrictions regarding the disclosure of the research performed. Blumenthal et al. (1996) surveyed life science faculties and companies supporting these faculties. They found evidence for the fact that delaying publications and restricting information sharing are quite common, for instance to allow enough time for the sponsoring company to file a patent application, or to protect the financial value of certain research results, or to avoid undermining the competitive status of the sponsoring company. Brooks and Randazzese (1999) mention other empirical evidence of the 'secrecy problem', but they also point to a possible effect of the research institute characteristics in the sense that the best research universities seem quite capable of protecting their traditional values of openness and seem to make only modest concessions to the practical needs of industry. In a study involving Norwegian university faculty, it was found that faculty with industry funding publish more than other researchers (Gulbrandsen and Smeby, in Geuna and Nesta, 2003).

Besides the 'secrecy problem', it can be noticed that both individual researchers and research institutions can develop financial interests in the specific research outcomes, leading to a possible bias towards certain fields and activities (ACE, 2001). This phenomenon brings us to one of the main concerns of the opponents of intensifying collaborations between universities and industries, namely that the academic research agenda will be 'contaminated' by the application-oriented needs of industrial corporations - the 'corporate manipulation thesis' (Noble, 1977). From this perspective, university research is considered as being characterized by an independence that should allow academics to freely contribute to theories and models at an endless science frontier, in a (purely) curiosity-driven way. The corporate manipulation thesis argues that corporations interfere with the normal pursuit of science and that they seek to control relevant university research to their own ends, rather than allowing faculty members to advance their research agenda through the pursuit of opportunities for federal and industrial funding[5]. The changes in the university research agenda are most often related to an alleged shift towards the more applied research end, referred to as the 'skewing' problem' (Florida and Cohen, 1999).

The empirical evidence on both problems appears to be mixed. Surveys by Rahm (in Florida & Cohen, 1999) and Morgan (in Florida & Cohen, 1999) found some empirical association between greater faculty involvement in industry and increased levels of applied research. Research centers that value the mission of improving industrial products and processes devote less of their R&D activities to basic research than centers that do not value this industry-oriented mission[6]. Additional evidence in this respect was found for Norwegian university faculty (Gulbrandsen and Smeby, in Geuna and Nesta, 2003). Here, it was found that faculty with industry funding performed significantly less basic research than researchers with no such external funds. In the same research setting, about 20% of the researchers reported contract research to be problematic for autonomy and independence of their research. In this respect it can be noticed that certain research centers have made collaboration with industry – or involvement in business networks – an explicit part of their mission. Likewise certain funding mechanisms favor cooperation between Industry and University as well in the US, Japan as in Europe

[5] For a recent overview on this debate within the field of Medicine, see Kelch (2002); with respect to policies adopted in order to address potential conflicts of interest within this field, see Drazen and Curfman, 2002.

[6] Centers that see improving industrial products and processes as part of their mission, spend about 19% of their R&D activities to basic research, while university centers that do not consider this as important devote about 61% of their R&D activities to basic research (Florida & Cohen, 1999).

(Florida & Cohen, 1999). Obviously, the direction of this relationship remains a question. On the one hand, it might be that researchers adjust their agendas in response to an increased cooperation with industry. On the other hand, industrial partners might anyhow turn to research centers with an application-oriented agenda rather than to centers known for performing basic research. In the latter case, the observed effect is only a selection effect.

At the same time, several studies react to the opponents of industry involvement on grounds of an alleged skewing in the research agenda. Those studies show that performing more applied research does not necessarily imply a trade off with basic research. For instance, data of the US National Science Board have shown that in the 1980s, although the number of university-industry research centers almost doubled, the overall share of university research, classified as basic research, remained quite stable. Hicks and Hamilton (1999) found that the percentage of basic research that was performed at universities remained unchanged between 1981 and 1995, a period during which at the same time, a sharp increase in university patenting could be observed. They also reported that the number of citations for university-industry papers was higher than that for single university papers, which would mean that university researchers may be able to enhance their scientific impact by collaborating with industry partners. Godin and Gingras (1999), when analyzing publication data of Canadian researchers over a fifteen year time period (1980-1995), conclude that: 'beliefs that collaborative research (with industry) is detrimental to academic research does not seem to empirically grounded'. Similar observations are advanced by Brooks and Randazzese (1999) within the US semiconductor industry, where a consortium of semiconductor-producers (SRC) funded university semiconductor research. No indication was found that the SRC support led academics to conduct less "foundational" research (Brooks and Randazzese, 1999). Recently, Owen-Smith (2003) highlighted the changed relationships between commercial and academic systems. Whereas these used to be separate systems, Owen-Smith's findings suggest that commercial and academic standards for success have by now become integrated in what is called a hybrid regime, where achievement in one realm is dependent upon success in the other. This observation has been confirmed by previous research in which the relationship between scientific performance and engagement in contract research with industry was examined more systematically (Van Looy et al. 2004). The findings revealed that contract research and scientific activities do not hamper each other: systematic engagement in contract research coincided with increased publication outputs, without affecting the nature of the publications involved. As resources increased, the positive relation between both types of activities became more outspoken, pointing towards a Matthew-effect.

Contract research, however, represents only one type of entrepreneurial activity occurring at universities. In the case of inventions, the potential conflict between public and private oriented considerations in terms of diffusion of knowledge (secrecy versus free dissemination) seems most salient. In that respect, analyzing publication outputs of academic inventors – and comparing it to that of non-inventors – can provide additional insights in whether an academic's entrepreneurial and scientific activities can be reconciled or whether they are of a more conflicting nature. Therefore, the number and the nature of publications produced by academic inventors will be the focus of this contribution. By comparing publication profiles of academic inventors with those of academic staff working in similar fields, who are not engaged in patenting activities, both the presence of the 'secrecy' and the 'skewing' phenomenon can be assessed. Whereas differences in terms of number of publications provide an indication of the trade offs between publishing within the scientific forum versus being involved in patentable technology development, differences in terms of the nature of publications can provide (counter-)evidence for the presence of 'skewing' or 'contamination' processes. Finally, given the findings reported by Van Looy et al. (2004) – these findings pointed to a positive relationship between involvement in contract research and publication output – involvement in contract research will be taken into account as a moderating variable. The following research questions are central to the empirical part:

- Do faculty members engaged in patenting activity (inventors) publish less than their colleagues in comparable research areas who are not engaged in such invention activities?
- Do inventors differ from colleagues (non-inventors) in terms of the nature of their publications? And if so, to what extent does this difference coincide with a shift towards more application oriented publications?
- To what extent does involvement in contract research with industry influence the co-existence of patenting and publication activities? Stated otherwise, to what extent do *both*

types of entrepreneurial activity – i.e. contract research and patenting – coincide with differential publication patterns?

3. Empirical Analysis

In this paper, we try to understand whether it is feasible to balance scientific and entrepreneurial activities by empirically examining the experiences of researchers at a particular university, namely the Catholic University of Leuven (K.U.Leuven), Belgium. First, we provide some background information on the approach followed at K.U.Leuven as to the transfer of knowledge and technology. We will then examine more closely the publication behavior of inventors, i.e. academic staff actively patenting the results of their research endeavours, in comparison to the publication behaviour of their peers working in similar fields. A comparison of publication activity will then allow addressing the central research questions raised in the previous section.

3.1. Situating the data: the Catholic University of Leuven, Belgium

Founded in 1425, the Catholic University of Leuven is one of the older universities in Europe and has approximately 30.000 students and 14 faculties, including not only engineering and medicine but also numerous and various disciplines in the social sciences, the arts and humanities. From the seventies and eighties onwards, K.U.Leuven has adopted a strategic stance towards knowledge transfer and the participation in regional and (inter)national economic development. Early on, a need was felt to develop context-specific structures and processes so that the university's fundamental values of teaching and research are complemented rather than hampered by its active engagement and involvement in the emerging processes of industrial and entrepreneurial innovation (Debackere, 2000). In order to create this supportive context, the University of Leuven founded K.U. Leuven Research and Development (LRD) in 1972, primarily oriented towards stimulating and supporting the knowledge and technology transfer between the academia and the industry. To this end, LRD offers advice as well as coordinative, administrative and legal support to its faculty members.

Three major activity poles can be discerned when looking at the activities of LRD. The first one involves an active patenting and licensing policy, implemented through the creation of an internal patent office and the establishment of a network of formal collaborations with different European patent attorneys. The establishment of a patent fund to help research groups cover the initial costs related to their patenting needs is yet another mechanism deployed by the first activity pole. A second activity pole is the creation of spin off companies. It implies the development and the deployment of the necessary mechanisms and processes to assist in business plan development and raising capital to start the venture. In order to achieve the latter, the university has created its own seed funds and growth fund in partnership with two major Belgian banking groups. By now, over 50 spin off companies exist, active across a wide variety of industries. Finally, the oldest and still most important activity pole of LRD is the administration of contract research, providing almost 25% of the university's R&D budget. LRD has developed the necessary processes for financial and personnel management to support these research activities and it provides the legal and intellectual property mechanisms to underpin these activities.

The maintenance of a dynamic balance between entrepreneurial and scientific activities is stimulated by a dual incentive system for members of LRD divisions. On the one hand, the striving for scientific excellence is rewarded through the hierarchical lines of the faculties and their departments. Excellence in entrepreneurship and industrial innovation, on the other hand, is rewarded through the LRD-structure. This structure offers financial autonomy and budgetary flexibility to the research divisions, allowing them to share in the possible benefits from their innovative and entrepreneurial activities. The question however remains as to whether this balance between scientific ambitions on the one hand and entrepreneurial activities on the other hand is actually being achieved. In other words, does the dual incentive structure for researchers at the university indeed stimulate a balance between scientific and exploitation / entrepreneurial activities, or do both activities interfere or even jeopardize one another, resulting in a de facto task division?

In order to obtain insights into this issue, we performed a detailed analysis of the publication performance and profiles of faculty members who are registered as inventors of EPO patents with application year between 1995 and 2001. We compared their scientific profiles to that of their colleagues working in similar fields but who are not registered as inventors.

As far as patent policy is concerned, K.U.Leuven R&D applies strict rules to protect the researchers' freedom to publish. The freedom to publish is always guaranteed. As a consequence, there can be a delay of at maximum 3 months before releasing a paper for publication in order to allow for the required patent procedures to be executed. In the majority of the cases, the publication delays experienced are less than two weeks.

3.2. Results

In a first step, all inventors – who are at the same time faculty at K.U.Leuven - have been identified for the time period 1995-2001. Inventors are defined as a) appearing in the inventor name fields of granted EPO patents during the time period 1995 – 2001; and 2) being employed by K.U.Leuven at the time of the invention as a member of the faculty (i.e. as a professor). Notice that this definition does not necessarily imply that the K.U.Leuven is acting as an assignee; in about half the cases, patents are held by companies within the framework of contract research agreements established with firms or obtained by firms afterwards (see in this respect also Balconi et al., 2002; Saragossi and van Pottelsberghe, 2003). In total 32 inventors- who are at the same time professor at K.U.Leuven - have unambiguously been identified. The total number of patents held by these inventors amounts to 70, with the number of patents held by individual inventors ranging from 1 to 8.

INSERT TABLE 1

As appears from table 1, the faculty of Medicine and Pharmaceuticals figures prominently within this sample (62,5%). This predominance can be related directly to the relative importance of patenting and licensing activities as a technology transfer mechanism for this discipline (while for instance, contract research and spin offs appear more frequently in the case of the Applied Sciences).

For each inventor, the total number of scientific publications, as retrieved via the web of science (library license), has been counted for the period 1998-2000. In a next step, a matching group has been formed consisting of faculty members (n=2-to-3 for each professor-inventor) working as a professor within the same discipline or field and with a comparable career profile[7]. This approach – that allows for paired sample comparisons – is appropriate given the field specific nature of the Web-of-Science publication output classification systems as it was also identified in previous research (Van Looy et al. 2004). In other words, we compare inventors and non-inventors who are publishing in the same disciplinary areas.

A straightforward paired sample t-test revealed that inventors publish significantly more than colleagues in similar fields and whose profile has similar characteristics both in terms of age and career progress and tenure (t=2,726, df =31; p=0,01). As is illustrated in table 2, the standard deviation is high, resulting from the presence within the sample of three inventors who have been involved in more than 90 publications (either as author or co-author) during the time period considered in our analysis. Hence, in a next step, these outliers have been removed from the analysis. As is obvious from table 2, the previous findings are confirmed, at a higher level of significance due to the reduction in variation.

INSERT TABLE 2

Nature of publications

Our second research question relates to the nature of the publications. Are inventors' publications of a different (e.g. more applied) nature than the ones of colleagues (non inventors) working in similar fields? In order to answer this question, the publications identified had to be characterised in greater depth. The nature of a publication is assessed according to the categorization developed by CHI within the framework of the SCIE databases. Each publication (journals or even journal issues) covered by the SCIE is classified into one of four categories that range from "applied technology" towards "basic scientific". In a first step, the publications are categorized as either 'technology-oriented' or 'science-oriented'. In a next step, a basic and applied orientation is distinguished, resulting in the four-class categorization summarized in Table 3 (see Godin, 1996).

[7] Both in terms of age, timing of different career steps (obtaining PhD – first appointment as professor) deviations of three years or less were allowed. In terms of full or part time occupation, the match had to be identical.

INSERT TABLE 3

First, the relationship between the nature of the publications and the presence or absence of 'inventorship' has been examined for the total group by means of a chi-square test[8]. Table 5 reports the observed and expected frequency values as well as the level of significance attained. We observe a highly significant relationship between both variables (p<0,0001). In other words, inventors publish considerably *less* than expected in technology-oriented journals (142 observed versus 207 expected publications). Inventors, though, do publish more in science-oriented journals, the difference between observed and expected values being most outspoken for category 3 ("Science oriented – Applied" type of publications).

INSERT TABLE 4

Second, similar analyses have been conducted for each discipline separately. The findings, reported in table 5, are in line with the results obtained for the total group: inventors do publish relatively more in science-oriented journals. At the same time, discipline differences become apparent. For Medicine and Pharmaceuticals as well as Agriculture, category 3 is more prevalent among inventors while for Sciences category 4 is prevalent. For Applied Engineering, a different picture emerges: inventors do publish relatively more in technology-oriented journals of a more basic oriented nature (category 2), and less in category 3 type journals.

Overall, our findings do not allow us to support the idea that involvement in technology development (as an inventor) implies a systematic shift towards publications of a more applied nature. For three of the four disciplines examined in this paper, inventors published relatively more within the more science-oriented journals. For the one discipline that did not reflect this pattern, applied engineering, a relative predominance of technology oriented publications of a more *basic* nature was observed, contradicting again what one might have expected based on some of the concerns raised in the literature on the "skewing problem".

INSERT TABLE 5

Inventors, Publications and Involvement in contract research

In previous research, the impact of the involvement of faculty members in contract research on publication output (both in terms of type and volume of output) has been analyzed. A positive relationship between volume of scientific publications - measured in a similar manner, i.e. publication output covered by the SCIE Index - and involvement in contract research became apparent (Van Looy et al. 2004). One of the elements identified to explain this positive relationship was the presence of research divisions[9]. These divisions were established at K.U.Leuven as an important transfer mechanism and are formed by – at least – three faculty members as a means to jointly expand their research activities. The size of those research divisions ranges from as few as 4 or 5 staff members to research groups consisting of 60 and more members. Given the positive relationship that was found between the differences in publication output of faculty involved in divisional activities (compared to colleagues working in similar fields but not being member of divisional structures) and the size of the research divisions, a next logical step is to extend the analysis towards including divisional membership as an explanatory variable. To this end, a more extended matching sample has been created, this time including both 'similar' colleagues participating in division activities as well as 'similar' colleagues not participating in division activities[10]. Table 6 summarizes the findings of an Ancova performed on the total number of publications as dependent variable with inventorship (Y/N), divisional membership (Y/N) and discipline (see table 1) as independent factors, and age as a covariate.

INSERT TABLE 6

[8] As we have created two control groups – one implying membership of a research division involved in exploitation of research, one excluding membership of such divisions- , the 'non inventors' group is larger than the group of inventors, resulting in a higher number of total publications, despite average numbers which are clearly lower as became apparent in the previous section.

[9] K.U.Leuven R&D, the technology transfer division of K.U.Leuven provides a legal and administrative framework for these research groups – that are fully integrated within K.U.Leuven – while the members of the division themselves are responsible for acquiring the funds deemed relevant for pursuing their activities.

[10] In theory this would lead to a total sample of 96 observations; unfortunately it was not possible to create two complete matching groups for all inventors (e.g. all colleagues with a similar profile being either or not involved in division activities), resulting in an overall sample which is slightly smaller (n=82).

As is apparent from Table 6, inventorship, division membership and discipline have significant main effects. For the inventorship independent variable, this main effect is positive in terms of publication volume (see table 2). The same applies to division membership (t=2,42, p=0,019). At the same time, the interaction effect 'division membership*inventor' is significant. Inventors who are also division members 'outperform' both their colleagues inventors who are not division members, as well as colleagues who are working within a research division without being inventor. These findings are in line with the positive effect of division membership on publication output as reported by Van Looy et al. (2004). They also point to the resource dependency of modern academic research activities: being a division member provides the researcher with more access to both scientific and financial resources because of the scale and scope effects that occur when several researchers pool their activities. Finally, we observe an interaction effect between discipline and division membership. Whereas publication outputs vary significantly with discipline – Agriculture and Sciences showing the highest numbers followed by Medicine and Applied Engineering – the positive impact of division membership is more outspoken in the case of Agriculture and Applied Science.

Overall, the findings obtained are straightforward: inventors publish systematically more than their colleagues who are not engaged in patenting activities but who are working in similar fields and who have comparable age and career profiles. In addition, involvement in research division activities further adds to the differential publication output.

Discussion

The evolving role and position of universities in the broader context of national and regional innovation systems has led to concerns on the feasibility of combining educational, scientific and entrepreneurial activities within universities. In this analysis, we have examined the relationship between scientific inquiry and science exploitation, whereby the amount and the nature of the publication output was the focus of analysis. Publication output from faculty at K.U.Leuven (Belgium), who appear at the same time as inventors on patents was compared to the publication output of scholars working in similar disciplines and having similar career profiles but who are not involved in patenting activities. This analysis led to the following major observations. First, inventors publish significantly more than their colleagues who work in similar fields and who have similar career characteristics, also when we take into account other variables (discipline, division membership) that might moderate the amount of their scientific output. As a consequence, involvement in inventive activities does not seem to hamper the "pure" scientific activities, at least not in terms of publication amount.

When taking into account the nature of the publications analysed, it turns out that, in general, inventors publish more in scientifically oriented journals than their colleagues who are not involved in patenting. The only exception relates to Applied Engineering. Here, inventors publish more in technology-oriented journals of a *basic* nature. Hence, the results from our data analysis do not confirm the presence of a skewing problem in terms of an alleged shift of publication output towards the more technology or applied end of the publication spectrum *at the expense* of more scientific or basic oriented publications. These findings suggest that so far, no trade off seems to have occurred between entrepreneurial and scientific activities. This supports Owen-Smith's (2003) 'hybrid regime' view of commercial and academic activities, where achievement in one realm is dependent on success in the other. Also, these results seem to provide some confirmation of the possible exploitation of research synergies, or the cross fertilization, that can occur when research topics in both activity realms are closely related (Carayol, 2003). On the basis of the present findings, we tend to conclude that it is feasible to organize both scientific and entrepreneurial activities, without one jeopardizing the other. Obviously, the appropriate institutional context has contributed to reaching this diversified and yet harmonized portfolio of activities, at least at K.U. Leuven. Debackere (2000) pointed to the importance of appropriate strategies, organizational structure and management processes to this end. The research division approach, juxtaposed on the Faculty structure, has created a de facto matrix structure. Crucial in terms of the well functioning of this structure is the presence of incentive arrangements of a dual nature, in which research excellence prevails along the hierarchical lines of the faculties and their departments and excellence in entrepreneurial innovation is rewarded along the lines of the LRD-divisions. At least in our study, this can be seen a key factor to achieve this balance.

Moreover, we should not forget that both publication and patenting activities are not that different when it comes down to their intellectual challenge and nature. In both instances, creativity, originality and novelty are key contributing factors both to publication output and patent performance. During the preparatory work we conducted for this research, a number of inventors even stated they felt that they increased the quality and the state-of-the-art character of their fundamental research questions based on the insights they obtained from a detailed scrutiny and awareness of the patent literature. In other words, by being involved in both realms of activity, they experienced interesting spillover effects that also benefited their scientific inquiries.

Our findings also point to several interesting and challenging directions for further research. First of all, they need to be complemented with research efforts aimed at 'external' validation, i.e. extrapolating beyond the K.U.Leuven boundaries, while using the same fine-grained type of data as applied within this analysis. Specific points of attention relate to latent, unintended or unwanted consequences of the phenomena observed and the precise nature of (institutional) arrangements that foster the co-existence of multiple objectives and hence the achievement of both scientific and entrepreneurial excellence. Such endeavors might add to our understanding of the contribution of institutional arrangements and incentive structures that might enable (or hamper) the feasibility of combining both types of activities in an academic context.

In addition, taking into account the impact of the publication output (in terms of citations) as well as the involvement of researchers in educational activities should be considered as moderating effects as well (Jensen & Thursby, 2002). Finally, a more longitudinally oriented analysis of patent and publication profiles might also add to a further understanding of the complex underlying cause-effect relationships that become apparent as the current transformations in academia are evolving.

To conclude, we are fully aware of the many tensions and problems that arise in the current transformation taking place across the university landscape. This transformation raises important questions as to the openness of the scientific "enterprise" as they have been well described by Richard Nelson in his recent article on the tensions between the market economy and the scientific commons (2004). It is obvious that the issues discussed by Nelson cut much deeper than the analyses and results reported in this paper. For instance, in order to obtain a fine-grained insight into any type of distortion that might occur as to the scientific mission of the university and its societal duty to disseminate the knowledge it creates, we should examine the activities of researchers and research groups involved in collaborations with industry into almost an ethnographic detail. By analysing publication output and patenting behaviour we are just scratching the surface. However, while scratching the surface, we have become aware of the fundamental complexity of the many demands that society at large imposes on its universities today. This complexity and the potential conflicts it entails, need a deep understanding. So far, our research has pointed to the fact that a symbiosis may indeed be possible. Understanding the positive but also the potentially harmful effects of this symbiosis is therefore an issue that should remain high on our research agendas.

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Table 1: Total number of inventors by discipline.

Discipline	*Number of Inventors*
Medicine & Pharmaceuticals	20
Applied Engineering	5
Science	3
Agriculture	4
Total	32

Table 2: Results of Paired sample t-test for Total Numbers of (SCIE) Publications Inventors/Non-Inventors

	Mean Difference	*Std. Deviation*	*Std. Error Mean*	*95% Confidence Interval of the Difference*		*t*	*df*	*Sig. (2-tailed)*
				Lower	*Upper*			
Complete Sample	24,14	50,12	8,86	6,07	42,21	2,72	31	,010
Sample Without Outliers	10,72	18,25	3,39	3,77	17,66	3,16	28	,004

Table 3 - Classification of nature of publications

Technology oriented	Applied --------	Type 1 ------	Applied technology
	Basic -----------	Type 2 ------	Engineering science-technological science
Science oriented	Applied --------	Type 3 ------	Applied research-targeted basic research
	Basic -----------	Type 4 ------	Basic scientific research

Table 4 – Relationship between Nature of Publications and Involvement in inventions

	Nature of Publications				
	Technology oriented Applied	Technology oriented Basic	Science Oriented Applied	Science Oriented Basic	Total
Observed					
Inventors	23	119	257	188	587
Non Inventors	79	221	186	181	667
Total	102	340	443	369	1254
Expected					
Inventors	47,75	159,15	207,37	172,73	587
Non Inventors	54,25	180,85	235,63	196,27	667
Total	102	340	443	369	1254
Significance	p<0,0001				

Table 5 – Relationship between Nature of Publications and Involvement in inventions – Breakdown by Discipline.

	Nature of Publications				
	Technology oriented Applied	Technology oriented Basic	Science Oriented Applied	Science Oriented Basic	Total
	Medicine & Pharmaceuticals				
Observed					
Inventors	12	57	179	78	326
Non Inventors	60	127	83	112	382
Expected					
Inventors	33,15	84,72	120,64	87,49	326
Non Inventors	38,85	99,28	141,36	102,51	382
Significance	P<0,0001				
	Agriculture				
Observed					
Inventors	0	9	53	59	121
Non Inventors	7	64	26	29	126
Expected					
Inventors	3,43	35,76	38,70	43,11	121
Non Inventors	3,57	37,24	40,30	44,89	126
Significance	P<0,0001				
	Applied Engineering				
Observed					
Inventors	11	49	16	2	78
Non Inventors	11	27	37	2	77
Expected					
Inventors	11,07	38,25	26,67	2,01	78
Non Inventors	10,93	37,75	26,33	1,99	77
Significance	P< 0,0025				
	Science				
Observed					
Inventors	0	4	9	49	62
Non Inventors	1	3	40	38	82
Expected					
Inventors	0,43	3,01	21,10	37,46	62
Non Inventors	0,57	3,99	27,90	49,54	82
Significance	P<0,0001				

Table 6: Ancova Results – Total number of (SCI) publications acting as dependent variable

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8084,403[a]	16	505,275	5,325	,000
Intercept	229,633	1	229,633	2,420	,125
Age (covariate)	57,804	1	57,804	,609	,438
Division Membership (DIV)	2930,278	1	2930,278	30,881	,000
Discipline (DIS)	2482,647	3	827,549	8,721	,000
Inventor (INV)	1731,204	1	1731,204	18,244	,000
DIV * DISC	1616,784	3	538,928	5,680	,002
DIV * INV	1070,976	1	1070,976	11,287	,001
DISC * INV	458,711	3	152,904	1,611	,195
DIV * DISC * INV	511,256	3	170,419	1,796	,157
Error	6167,821	65	94,890		
Total	34806,213	82			
Corrected Total	14252,224	81			

[a]R Squared = 0,567 (Adjusted R Squared = 0,461)