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COMBINING ENTREPRENEURIAL AND SCIENTIFIC
PERFORMANCE IN ACADEMIA: TOWARDS A
COMPOUNDED AND RECIPROCAL MATTHEW
EFFECT?

by

B. VAN LOOY
M. RANGA
J. CALLAERT
K. DEBACKERE
E. ZIMMERMANN

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Combining Entrepreneurial and Scientific Performance in Academia: Towards a compounded and reciprocal Matthew Effect?

Bart Van Looy¹ (*Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Belgium*)

Marina Ranga (*Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Belgium - Science and Technology Policy Research SPRU, University of Sussex, UK*)

Julie Callaert (*Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Belgium*)

Koenraad Debackere (*Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Belgium - K.U.Leuven R&D, Belgium - Steunpunt O&O Statistieken, K.U. Leuven, Belgium*)

Edwin Zimmermann (*Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Belgium - K.U.Leuven R&D, Belgium*)

The increase of entrepreneurial activity within academia has raised concerns that the research orientation of universities might become ‘contaminated’ by the application-oriented needs of industry. Empirical evidence on this concern is scarce and ambiguous. We examine whether entrepreneurial and scientific performance in academia can be reconciled. Our empirical findings (K.U.Leuven, Belgium) suggest that both activities do not hamper each other; engagement in entrepreneurial activities coincides with increased publication outputs, without affecting the nature of the publications involved. As resources increase, this interaction becomes more significant, pointing towards a Matthew-effect. We finally suggest that balancing both activities further depends on the institutional policies deployed.

Keywords: Knowledge interactions; Innovation systems; University–industry relations

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¹ All correspondence regarding this article should be sent to: Bart Van Looy, Research Division INCENTIM, Faculty of Economics and Applied Economics, K.U.Leuven, Naamsestraat 69, 3000 Leuven; Belgium – (Tel) +32 (0)16 32 69 01 – (Fax) +32 (0)16 32 67 32 – (Email) Bart.vanlooy@econ.kuleuven.ac.be

Introduction: Entrepreneurial Universities

Although far from new, science-industry relationships have received broader attention over the last decades, not at least due to an increasing recognition of the fundamental role of knowledge and innovation in fostering economic growth, technological performance and international competitiveness. Scholars of innovation studies (e.g. Freeman, 1987, 1994; Lundvall, 1992; Nelson, 1993; Nelson and Rosenberg, 1993; Mowery and Nelson, 1999; Dosi, 2000) have described and analyzed the complex interactions between the institutional actors that play a role in the process of knowledge generation and diffusion. The concept of 'innovation systems' has therefore gained widespread acceptance since the mid-1980s and has been used as a general framework for designing innovation policies and adequate institutional arrangements in support of those policies (OECD, 1999; European Innovation Scorecard, 2002). Within these models, 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 with respect to the innovative potential of society.

Departing from the traditional science-industry partnership model highlighted in the 'old' economics of science that dominated since the 1960s (e.g. the linear model of knowledge production and diffusion), newer insights into the University-Industry interaction emerged in the 1990s. They were based on the concepts of scientific networks (Pavitt, 1997; Steinmueller, 1994; David, Foray and Steinmueller, 1997), strategy, structural analysis of industries and competitors (Porter, 1995), and a new vision on industry, academia and government interactions as encompassed by the 'Triple Helix' model (Etzkowitz & Leydesdorff, 1997, 1998; Leydesdorff & Etzkowitz, 1996; 1998).

Closely associated with the Triple Helix model, the notion of 'entrepreneurial universities' (Branscomb, Kodama & Florida, 1999; Etzkowitz, 1998; Etzkowitz, Webster & Healy, 1998) has increasingly been used in relation to the spectrum of evolutions faced in recent years by academia: more involvement in economic and social development, more intense commercialization of research results, patent and licensing activities, the institutionalization of spin off activities and managerial and attitudinal changes among academics with respect to collaborative projects with industry. As a consequence, one might speak of a 'second academic revolution' during the 1990s, adding entrepreneurial objectives as a third component to the mission of the university, after research had complemented education as an inherent part of university's mission during the 19th century, the so called 'first academic revolution'.

In fact, a multitude of elements contributed to the growth of this entrepreneurial phenomenon; which, at least in the US should be seen as a logical extension of the successful engagement of university research in fields such as space, defence and energy during the 1940s, 50s and 60s². Among these explanations, shifts in federal funding (US), as well as changes in the tax treatment of R&D expenditures have been

² 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).

identified as important. In addition, in the US, one observed during the eighties a shift in priorities, favouring R&D that would contribute to American productivity and global competitiveness (Cohen and Noll, 1994). Moreover, 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 become 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 and the right to commercialize the results obtained. Such measures gave a significant boost to the adoption or the further professionalization of IPR-related procedures and policies, while contract research conducted at universities was more and more considered an inherent part of the mission of today's universities. (Branscomb et al. 1999; Etzkowitz & Kemelgor, 1998; Van Looy, Debackere & Andries, 2003). Finally, 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 the findings of the latest research; hence, it should come as no surprise that universities and knowledge creating institutions find themselves in an advantageous position to contribute 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 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 start acting as a shareholder), science parks and business incubators. Such new arrangements all reflect the enlarged role of research institutes. As a recent CORDIS (2001) 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).

All these bridging institutions and accompanying policy measures 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, on the one hand, cannot be seen in dissociation from the transformations that marked business R&D over the last two decades, on the other hand. These changes imply more competition on international technology markets, accelerated transition 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 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, consortia with universities, government laboratories, other companies etc., at the national or international level (Etzkowitz, 1998; Mowery & Nelson, 1999).

Hence, the combinatory effects of these factors are responsible for an overall increase in 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. But whether we look at Europe, the US or Japan, entrepreneurial universities have become a reality that cannot be ignored; substantiation of this reality can be found in the indicator frames for assessing knowledge-generating institutes, which start to include more entrepreneurial oriented indicators more systematically³ (for a more detailed discussion, see Van Looy et al., 2003)

Boundaries and concerns

The increasing trend of developing entrepreneurial capabilities within academia has given rise to several concerns related to the role of academia in society and even urges some to utter the need for a new 'social contract' between science and society (Gibbons, 1999; Kelch, 2002; Martin, 2001, 2002). The main concerns originate in the fundamentally different reward and incentive systems of academia and private sector research, in terms of the relationship between disclosure and secrecy and its implications, and the complementarities and substitution effects between public and private R&D expenditures (Dasgupta and David, 1987, 1994). A fear often expressed is related to the impact of University-Industry co-operation on universities' research agenda (Geuna, 1999; Hane, 1999; Vavakova, 1998) and the conflicts of commitment 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 -, although most universities have formal policies regarding and regulating this issue (ACE, 2001).

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 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 research conducted and the access to research results (Hane, 1999) and is even re-opening debates on the norms and values guiding academic science (see for instance, Merton, 1968; 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. Florida and Cohen (1999) referred to this as the 'secrecy problem' within research universities. Empirical evidence has indeed shown an association

³ 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.

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 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. Mechanisms and policies on intellectual property rights aim at formally regulating these issues. In this respect, Mowery and Nelson (1999) pointed to the higher transaction costs associated with the increased licensing and royalty regulations.

In addition, 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 brings us to one of the biggest concerns of the opponents regarding an intensification of 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). This view obviously counters the theory on academic entrepreneurship (Etzkowitz et al., 1998, 2000; Slaughter & Leslie, 1997). 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 for their own ends, rather than faculty members advancing their research agenda through the pursuit of opportunities for federal and industrial funding (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). However, this thesis is not always validated in reality, as illustrated by some of the findings of the detailed Carnegie Mellon survey of US university-industry research centers, conducted by Cohen et al. (1994, in Florida & Cohen, 1999). The results of the survey show that university research centers mostly claim to be the prime movers in the development of closer university-industry ties, although their decision was conditioned by federal science and technology policies. This finding contradicts to a certain extent the corporate manipulation thesis, but the fact that universities were the prime movers does not necessarily imply that their original research agenda remained unchanged.

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). Again, the empirical evidence on this problem 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. The above-mentioned Carnegie Mellon survey found research centers that value the mission of improving industrial products and processes to devote less of their R&D activities to basic research

than centers that do not value this industry-oriented mission⁴. In this respect it can be noticed that certain research centers have made collaboration with industry an explicit part of their mission; likewise certain funding mechanisms favor cooperation between Industry and University both in the US, Japan and Europe alike (Florida & Cohen, 1999) There is indeed empirical evidence revealing that ties with industry are associated with more applied research conducted by faculty. Obviously, the direction of this relationship remains a question. On the one hand, it might be that research centers adjust their agenda 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. Finally, it might still be a more complex, simultaneous societal phenomenon. Indeed, all scientists are citizens as well. As a consequence, consciously or less consciously, they are influenced by major societal trends (that they may in turn help shape). One of those trends is the multiple actor perspective on knowledge creation and dissemination (the knowledge society). So, it would be a much broader issue than universities adapting their research agenda to industry of industries shaping academic agendas. It might just also be a general cultural, societal phenomenon whereby the different components in the triple helix just “undergo” a paradigm shift into how culture and society treat knowledge and its development (see in this respect as well, Etzkowitz, 1994; Etzkowitz & Gulbrandsen, 1999; Leydesdorff & Etzkowitz, 2003).

On the other hand, some empirical evidence also shows 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 1980’s, although the number of university-industry research centers almost doubled, the overall share of university research, classified as basic research, remained quite stable. Also, in the US semiconductor industry, an in 1982 founded consortium of semiconductor-producers (SRC) funded university semiconductor research. Faculty interest also led to research proposals for government support, and over a 10-year period, the semiconductor industry had leveraged over double or triple the amount of money invested in the consortium. However, there was no indication that the SRC support led academics to conduct less “foundational” research (Brooks and Randazzese, 1999).

As these transformations are observed within numerous universities, they point to the quest for a new balance between the different objectives and activities taking place at and required from universities. Traditional roles associated with teaching and research (need to) become reconciled and complemented with activities that reflect an active contribution towards industrial and entrepreneurial innovation. Within this paper, we want to add to our understanding of this balancing act by examining more in depth the experiences of a particular university, namely the Catholic University of Leuven (K.U.Leuven) situated in Belgium. First, we provide some background information on the approach followed at K.U.Leuven with respect to the transfer of knowledge and technology. We will then examine more closely the activities taking place at the level of

⁴ 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 centres that do not consider this as important devote about 61% of their R&D activities to basic research (Florida & Cohen, 1999).

academic research groups, especially with respect to their scientific output. We will consider the number and the nature of publications produced by academic staff actively involved in contract research with industrial partners and compare the results obtained with publications of academic staff in similar fields, but who are not engaged in such industry-university research activities in a systematic way. The following research questions hence are central to the empirical part:

1. Do faculty members, who are systematically involved in contract research with industry, publish more or less than their colleagues in comparable research areas and faculties who are not engaged in such systematic endeavors?
2. Do faculty members, who are systematically involved in contract research with industry, have different publication profiles (applied versus basic) than their faculty colleagues?
3. Is there a shift over time in the differential publication profiles observed?

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 social sciences, 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 the early 1970's. primarily oriented towards stimulating and supporting the knowledge and technology transfer between the academic and the industrial spheres. To this end, LRD offers advice, coordinative, administrative and legal support towards its faculty members.

Three major activity poles can be discerned when looking at the activities undertaken at LRD. The first one involves an active patenting and licensing policy, implemented through the creation of an internal patent liaison 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 venture capital. In order to achieve the latter, the university has created its own seed funds and growth fund in partnership with two major Belgian banks. 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 offers 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.

One specific enabling structure that has been conceived in this respect consists of so-called research divisions. Although embedded within the university, research groups can decide to organize their contract research and other exploitation activities semi-autonomously by establishing a research division. In return for some percentage overhead on the contract turnover LRD staff handles the legal, financial and administrative implications of the activities. The founding faculty members can act with large degrees of freedom regarding the strategic orientation of the research division, including allocation decisions on (financial) resources accumulated over time. Over 40 LRD divisions execute most of the contract research at K.U.Leuven. They are operating at the cross section of the academic and the industrial system. Faculty members from different faculties and departments support the K.U. Leuven research divisions. Currently they employ over 400 researchers. They are further entitled to participate in the spin off companies that build on the knowledge and/or technology developed within the research divisions.

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 possible benefits from their innovative and entrepreneurial activities.

The question however remains as to whether this balance with respect to scientific ambitions on the one hand and entrepreneurial, contract research oriented, 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 analyzed in detail the publication performance and profiles of faculty members engaged in divisional activities. In addition, this analysis implied a systematic comparison in terms of scientific performance, as measured by publications, with colleagues working in similar fields albeit not involved in contract research in such a systematic manner.

Several research questions will be addressed. We start with the general question whether division members publish more or less than their colleagues who are non-division members. In a second part of the analysis, we try to map possible effects on the academics' research agenda by investigating whether or not the nature of the publications differs between division members and non-division members. (note: always use the terminology division versus non-division members; this is more accurate since they are all faculty members anyway) In other words, we attempt to evaluate the assumption that academics involved in contract research display a more applied publication profile than their colleagues not engaged in such systematic university-

industry collaborative agreements. Finally, it should be noted that our understanding of cross-sectional differences in publication behavior between the two groups (if any) can be enhanced by introducing a longitudinal perspective as actual differences “here and now” do not reveal the direction of underlying tendencies. Hence, in a last part of our analysis we will address the evolution over time of scientific performance as measured by publications, both for division and for non-division members, including a breakdown by publication type.

Findings

The sample used for this analysis consists of 14 LRD divisions, 8 of which are related to the Faculty of Applied Sciences. The remaining divisions belong to the Faculty of Medicine, the Faculty of Sciences, the Faculty of Agricultural Sciences and the Faculty of Pharmaceutical Sciences. The domains of Arts & Humanities and Social Sciences were not included in the selection, as the majority of them have been established only very recently⁵. Division ages range from 4 to 18 years, with an average of 11 years of existence. The average yearly division turnover ranges from less than 20.000 Euro to over 2.000.000 Euro, with an average of around 640.000 Euro⁶.

In this analysis, publication output is considered an indicator of scientific performance. For this analysis, only SCI covered publications have been taken into account, given the systematic availability of the data as they are available to all Flemish universities given the WoS License of the Flemish Minister of Education with ISI. For each division and for the represented faculties, we assessed the publication performance of the faculty involved (professors). Both the amount of publications and the nature of the publications were taken into account. The nature of a publication is assessed according to the categorization developed by CHI within the framework of the SCI databases. Each publication (journals or even journal issues) covered by the SCI is classified into one of four categories that range from “applied technology” towards “basic scientific”. At a first level, the publications are categorized as either ‘technology-oriented’ or ‘science-oriented’. At a next level, a basic and applied orientation is distinguished, resulting in the four-class categorization (Godin, 1996) summarized in Table 1.

INSERT TABLE 1

For the assessment of publication performance, faculty members (professors) are included in the analysis. The number of professors involved in the divisional research ranges from 2 to 11, with an average of 6. Their publication behavior is compared to that of colleagues belonging to the corresponding faculty, and at the same time not belonging to any division. As an age difference in both groups might bias publication amounts and hence observed differences in terms of publications, the comparison group was selected in such a way that the average ages for the groups that are being compared

⁵ For the same reason, some divisions situated in the fields of Medicines and Applied Engineering have not been included (division age < 5 years).

⁶ Data on the research divisions were made available through the annual reports of K.U.Leuven R&D.

are indeed comparable. A posteriori verification revealed no significant age differences, legitimating a comparison with regard to their publication behavior ($t = -0.560$ --- $p=0.576$). Moreover, the groups that have been matched always belong to the same discipline so as to avoid differences caused merely by discipline effects. Finally, it can be observed that comparing within the same university gives this analysis a quasi-experimental nature as the broader institutional context - at different levels - is comparable for all faculty involved.

Do faculty who are systematically engaged in contract research publish more or less than their colleagues who are not?

For each of the 14 divisions in our sample, we calculated the number of publications per professor for the period of 1998 until 2000 (as registered in the SCI-Expanded publication database and available at all Flemish universities). This allowed calculating the yearly average number of publications per scholar for each of the divisions involved. For the same period, the publications were counted and averaged for members of the represented faculties who are not involved in contract research.

An ANOVA was performed to establish the influence of discipline and of division membership on the number of publications. The results are presented in Table 2, showing that both discipline and membership of a division strongly influence the number of publications. As for disciplines, the highest publication levels (for division as well as non-division members) are to be found within pharmaceutical sciences (7.43), agriculture (6.64) and medicine (5.99), closely followed by sciences (physics, mathematics) (5.34). Applied Engineering closes this ranking with distinctively lower publication counts (2.91).

INSERT TABLE 2

Table 3 presents the results on the differences in terms of yearly average number of publications between division members and non-division members, categorized per discipline.

INSERT TABLE 3

From this table it becomes clear that the division members in our sample publish more than their colleague non-division members in the matched comparison group. A paired samples t-test reveals that the resulting differences are significant at the 0.01-level ($p=0.001$). Overall, the results are straightforward (and significant). Researchers actively involved in research divisions publish more than their colleagues who are not. Although this analysis does not allow for definite conclusions with respect to the direction of causality between membership of a division and scientific performance - as measured by number of SCI publications - these first-order results suggest that combining scientific and entrepreneurial performance may indeed be feasible.

These findings at first sight seem to suggest that entrepreneurial activities, taking place within the research divisions operating at K.U.Leuven do not jeopardize scientific activities, at least when using the total amount of publications as a dependent variable. However, concerns have been raised that involvement in contract research has a "skewing effect" on academics' research agenda, in the sense that there would be a shift

from basic research to more applied research (cf. supra). Hence, our next research question addresses this concern by looking into the type of the publications produced by division members on the one hand and by non-division members on the other hand.

Is there evidence for the ‘skewing problem’?

To check whether contract research directs the research agenda of entrepreneurial academics towards a more applied orientation, additional analyses were conducted that explicitly take into account the nature of the publications. The basic-applied continuum combined with the science-technology distinction, equivalent to the abovementioned SCI categorization has been used. An Anova was performed to examine the degree to which publication numbers are influenced by discipline (Applied Science, Medicine, Sciences, Pharmacology and Agricultural Sciences), division membership (0/1), science or technology domain (0/1) as well as the basic versus applied domain (0/1). The results of this analysis, with the number of publications as dependent variable, can be found in table 4.

INSERT TABLE 4

Although the interaction effects are our major concern here, let us first briefly discuss the main effects, which to a large extent confirm previous findings. Both discipline and division membership significantly affect the amount of publications. The nature of publications in terms of Basic versus Applied, does not reveal any significant differences. Stated otherwise, both categories are found in equal amounts and variations within the sample examined. This is not the case for the Technology/Science distinction. Articles are more frequently found in science domains than within technology domains. Of course, for the purpose of our analysis, the interaction effects are of major concern. If the ‘skewing problem’ would manifest itself, interaction effects are to be expected between division membership on the one hand, and the applied/basic and/or technology/science distinction on the other hand. Moreover, hypothesized differences – if the skewing problem would be present – would go into the direction of more applied publications in the case of division membership, whereas the opposite would hold for basic publications.

As for the second order interaction effects, table 4 first indicates differential effects with respect to the technology/science distinction depending on the discipline (‘DISC * T/S’). While overall, more publications are to be found within science domains, this is not the case when Applied Engineering and Medicine are considered separately. For both disciplines, publication numbers within technology domains are higher than publication numbers situated within scientific domains, while the opposite holds for the three other disciplines involved (Sciences, Pharmacology, Agricultural Sciences). In addition, the gap between the amounts of science- and technology-oriented publications is wider for the three latter disciplines.

Of central interest are of course the interaction effects in which division membership acts as one of the variables. As for the second order effects, significant results are found in combination with both the applied/basic and technology/science distinction. Surprisingly, the results do not point into the direction of the ‘skewing’ effect as expected. This becomes clear when inspecting Table 5, which depicts the

average number of publications (per faculty/per year) broken down in the applied/basic and science/technology categories respectively for both faculty involved in divisions and their colleagues who are not.

INSERT TABLE 5

First of all Table 5 illuminates again the main effects discussed above; while no significant differences are found with respect to the basic/applied distinction (0,98 versus 1,07), such differences do manifest themselves with respect to the science/technology categorization (0,68 versus 1,37). However, the most salient observation in Table 5 relates to the differentiated patterns related to the distinction basic/applied and science/technology. Division members publish more in applied fields (0,53 versus 1,14) while at the same time the average number of publications within basic fields is of a similar magnitude (1,1 versus 1,06). As for the science/technology distinction, division members publish more on average within both categories, the difference being considerably larger for science (1,46 versus 1,09) than for technology (0,73 versus 0,54). In terms of the 'skewing phenomenon', these figures indeed reveal that division members publish more in applied fields. However, this difference apparently does not manifest itself 'at the expense' of the amount of publications of a more basic nature.

For the science/technology distinction, our findings even suggest that division membership is leveraging both the amount of publications of a scientific and of a technological nature. Both these observations immediately explain the significance of the third order effect with respect to division membership, the applied/basic distinction and the science/technology categorization ('DIV * A/B * T/S'). Finally, a second third order interaction manifests itself as significant (Discipline, Division membership and Science/technology orientation of the publications ('DISC * DIV * T/S'); here the aforementioned interaction effects of discipline and the predominance of science or technology oriented publications intermingle with division membership. For applied engineering and medicine, division members perform better within technology-oriented publications; while at the same time similar numbers are found within the science oriented categories. For all other disciplines implied in this analysis (sciences, pharmacology, agricultural sciences), division members publish more in both categories (science/technology) than their counterparts not involved in divisional activities. Figures 1 through 5 provide graphical overviews for these second order interaction effects.

INSERT FIGURES 1 THROUGH 5

Hence our findings are straightforward; division members publish more than their colleagues not involved in divisional activities for three out of the four categories used in this analysis. Even when taking into account second and third order interaction effects, this basic pattern does not change: division members never publish less than their colleagues not involved in divisional activities, and for the majority of the categories, they even publish more.

Of course, it can be noticed that all previous analyses were conducted by making use of publications between 1998 and 2000. They result in a profile of publication

behavior for both division and non-division members at a certain point in time, hence providing a static image. They thus do not allow for any inference in terms of underlying shifts over time; as such, inferences in terms of ‘leveraging’ are a bit premature. As the ‘skewing’ phenomenon is by definition a process, a longitudinal approach is needed to complement the findings reported so far and to prove clues about the underlying dynamics. In the next section, this issue is explored through an analysis of publication behavior over a longer time period.

The skewing problem once more: does the nature of publications shift over time?

In order to clarify whether or not a shift occurs in the nature of publications, we assessed the publication behavior of division and non-division members over a nine-year period (1991-2000). This analysis implied a sample reduction. First of all, only divisions that have existed for a time period of 9 years can be used in this analysis. In addition, only divisions with stable membership throughout the time period examined have been withheld. These restrictions implied that an analysis could only be made for the research divisions situated within the field of Applied Engineering (n= 8).

For the divisions that met these criteria, correlations (Kendall τ) have been calculated. The first variable consists of the difference in terms of number of publications between division and non-division members, both for the total number of publications and for the number of publications broken down into the different categories outlined above. The second variable consists of the years involved in the 9-year period. Table 6 summarizes the findings.

INSERT TABLE 6

As table 6 and figure 6 make clear, the gap between division and non-division members widens over time in a significant manner for the total number of publications as well as the publications in category 1 and 2, covering publications of a technology oriented nature. It should be noticed that for this discipline, applied sciences, both of these categories account for the majority of publications counted (>75%). Again, this finding confirms the results of the previous analysis. For a faculty of applied sciences, one might expect increases in technology-oriented outputs, both for division and non-division members alike. The fact that they are increasing at a stronger rate for the division members than for the non-division members might point to the fact that, thanks to their more frequent and systematic involvement with industrial partners, division members have a higher access to and awareness of the current state-of-the-art in terms of technological problems in industry, and hence have more “food for thought and publication” leading to increasing differential technology-oriented publication counts. The most important finding in Table 6 then is the lack of a significant difference for the type 3 and 4 categories. When growing increasingly performant in technology-oriented publications, the faculty involved in divisional activities keep their performance a par with their non-divisional colleagues as it comes to the science-oriented publication output. Hence, our data suggest no evidence whatsoever for the skewing problem in terms of shifting towards the more applied spectrum at the expense of more basic oriented publications.

INSERT FIGURE 6

While we already hinted at one possible explanation of the phenomena observed so far, namely the higher awareness of the state-of-the-art in industrial technology issues, another potential explanation immediately comes to mind. The feasibility of combining entrepreneurial and purely scientific activities might (partly) stem from the availability of additional resources – and hence research staff – related to contract research activities. If this would be the case, introducing the size of the division might lead to a further accentuation of the findings obtained so far. Hence, for each division, the ratio between the number of publications of division members and the number of publications of the matched non-division members has been calculated. Relating this ratio to the division's yearly average turnover indeed revealed a positive relation ($r=0.80$; $p<0.01$), which is illustrated in figure 7. Moreover, overall divisions grow over time in terms of size and hence (human) resources ($r=0.85$, $p<0.01$), resulting in a situation of 'gaps' widening over time.

INSERT FIGURE 7

Conclusions and discussion

The shifting role of universities and knowledge centers within the broader framework of innovation systems, has led to some concerns about the feasibility of combining educational, scientific and entrepreneurial oriented activities within universities. In this analysis, we examined the relationship between the latter two, whereby the amount and nature of publications was a focal point of attention. Publication output from faculty at K.U.Leuven (Belgium), structurally involved in contract research, was compared to publication output of scholars working in similar disciplines. This analysis led us to the following observations. Firstly, scientific output is clearly related to division membership. Publication amount and differences between division and faculty members depend on the discipline under consideration, but overall, division members publish more than their faculty colleagues. Hence, at first sight, the performance of contract research does not seem to hamper scientific activities.

When taking into account the nature of the publications, it turns out that division members publish more than their colleagues not involved in divisional activities for the majority of the categories used in this analysis to characterize this nature. Even when taking into account second and third order interaction effects, this basic pattern does not change: division members never publish less than their colleagues not involved in divisional activities, and for the majority of the categories, division members publish more. Hence, our data suggest no evidence for the skewing problem in terms of shifting towards the more applied spectrum *at the expense* of more basic oriented publications; similar conclusions can be drawn with respect to the science/technology spectrum.

These findings suggest that no trade off seems to have occurred between entrepreneurial and scientific activities within our sample of LRD divisions. On the contrary, involvement in contract research seems to stimulate the scientific activities of divisions, resulting in larger publication outputs, accumulating over time. In this respect, it turns out that the bigger the scale of the research division, the bigger the difference in general publication output becomes. Hence one is inclined to suggest that it is indeed feasible to leverage contract research and the implied resources towards

improving the scientific capabilities of the academic staff involved (in terms of publication output). As such, these findings are in line with the well-known Matthew Effect (Merton, 1968, 1988) to such an extent, that one is even tempted to coin the idea of a “compounded” Matthew-effect. Whereas the Matthew effect as described by Merton (1968) focused on the often disproportional amount of credit already famous scientists obtain for work done jointly, Merton (1988) later on also pointed at effects with respect to the allocation of scientific resources. The findings reported here indicate not only that the “rich get richer” but also that the ‘diversity’ of their richness increases. In other words, the Matthew effect does not only apply to the amount of publications (quantity) but can be observed as well in terms of the nature of the publications. At the same time, differential publication rates seem strongly associated with the amount of resources implied in divisional activities, which grow steadily over time. Hence, our findings suggest that performance in both areas (scientific excellence as measured by number and nature of the publications) and entrepreneurial performance (as measured by the size of the budget of the division) mutually reinforce; resulting not only in a compound Matthew effect, but also into the direction of a Matthew effect as it encompasses both activity domains.

From these results, we tend to conclude that it is indeed feasible to organize both scientific and entrepreneurial activities, without one jeopardizing the other. Obviously, the appropriate institutional context has contributed to reaching such a diversified and yet harmonized portfolio of activities. Debackere (2000) pointed out the importance of appropriate strategies, organizational structure and management processes in this respect. The research division approach, juxtaposed on the Faculty structure has created a de facto matrix structure. Crucial in terms of the well functioning of such a 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 at K.U.Leuven, this has been a key contributing factor in achieving this balance.

Our findings also point out several 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, though using the same fine-grained type of data as applied within this analysis. Such complementary analysis’s are needed to confirm the relevancy and robustness of the suggestions made with respect to the ‘compounded’ Matthew effect spanning scientific and entrepreneurial activities. Specific points of attention, in this respect 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 addition, recent work of one of the co-authors has identified additional elements that contribute to the phenomena observed. These relate to the nature of the industrial partners involved, and more specifically their R&D capabilities (Ranga, 2003). Finally, it can be observed that our analysis implied research divisions active within the domain of more exact sciences; the question can be raised – and hence examined – whether the same dynamics can be observed within the social sciences.

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TABLE 1 - 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 2 – ANOVA results with regard to influence of discipline and division membership on number of publications

	F Value	Significance
Division Membership	36.757	0.000
Discipline	20.475	0.000
Division Membership *	3.309	0.011
Discipline		
Adjusted R square model : 0.163 (df=9)		

TABLE 3 – Difference in average publication amount between division members and non-division members active in similar disciplines

Faculty/Discipline	Division number	Δ yearly average number of publications (division members – faculty members)
Applied Sciences	1	0.45
	2	0.56
	3	1.72
	4	0.91
	5	4.22
	6	0.58
	7	6.10
	8	2.25
Medicine	1	1.33
	2	0.22
Agricultural Sciences	1	6.97
	2	4.49
Pharmaceutical Sciences	1	5.21
	1	3.67
Mean difference (division – faculty) = 2.76 Median difference (division – faculty) = 1.98 Paired samples t-test: p =0.001		

TABLE 4 – ANOVA to assess the impact of discipline, division membership and the nature of the publications on the total amount of publications

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	108,149	39	2,773	5,879	,000
Intercept	74,603	1	74,603	158,164	,000
Main Effects					
Discipline (DISC)	14,407	4	3,602	7,636	,000
Division Membership (DIV)	8,623	1	8,623	18,280	,000
Applied/Basic (A/B)	0,250	1	0,250	0,529	,472
Technology/Science (T/S)	18,910	1	18,910	40,091	,000
Interaction Effects					
DISC * DIV	4,198	4	1,049	2,225	,086
DISC* A/B	0,920	4	0,230	0,488	,745
DISC * T/S	19,184	4	4,796	10,168	,000
DIV * A/B	2,303	1	2,303	4,883	,034
DIV * T/S	5,801	1	5,801	12,299	,001
A/B * T/S	1,655	1	1,655	3,509	,069
DISC*DIV*A/B	2	4	0,5	1,060	,390
DISC* DIV*T/S	8,689	4	2,172	4,606	,004
DISC*A/B*T/S	0,681	4	0,170	0,361	,835
DIV*A/B * T/S	3	1	3	6,361	,016
DISC* DIV * A/B * T/S	1,517	4	0,379	0,804	,531
Error	16,891	36	,472		
Total	204,779	76			
Corrected Total	125,129	75			

a R Squared = ,864 (Adjusted R Squared = ,717)

TABLE 5 – Average number of publications (yearly) broken down by nature of publications and division membership

	Applied	Basic	Total (averages)	Technology	Science	Total (averages)
Non division members	0,53	1,1	0,81	0,54	1,09	0,81
Division members	1,14	1,06	1,10	0,73	1,46	1,10
Total (averages) ⁷	0,98	1,07	1,02	0,68	1,37	1,02

⁷ For the total averages relating to division members, n=28, resulting from 14 divisions multiplied with two (as each distinction implies two categories); for the total averages relating to faculty (non division members), n=10 as 5 disciplines (multiplied by two) are implied in the data set used. Total averages are hence weighted averages with different weights relevant for rows and colons respectively.

TABLE 6 – Correlation between division age and difference in number of publications between division and non-division members (for a period of 10 years: 1991-2001)⁸

	Kendall – Tau correlation	Significance (p value)
Total publications	0.643*	0.026
Publications type 1	0.714*	0.013
Publications type 2	0.643*	0.026
Publications type 3	0.357	0.216
Publications type 4	- 0.214	0.458

* p<0.05

⁸ For the calculations, one outlier was removed from the analysis.

FIGURE 1 – Interaction effect between division membership and type of publications in Applied Sciences

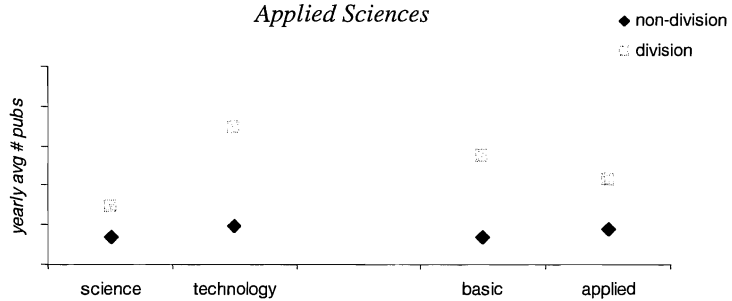


FIGURE 2 – Interaction effect between division membership and type of publications in Medicine

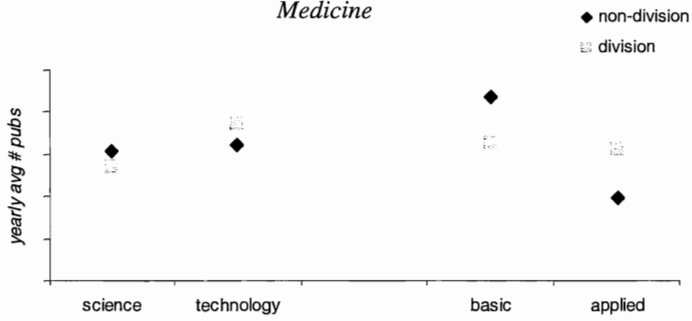


FIGURE 3 – Interaction effect between division membership and type of publications in Agricultural Sciences

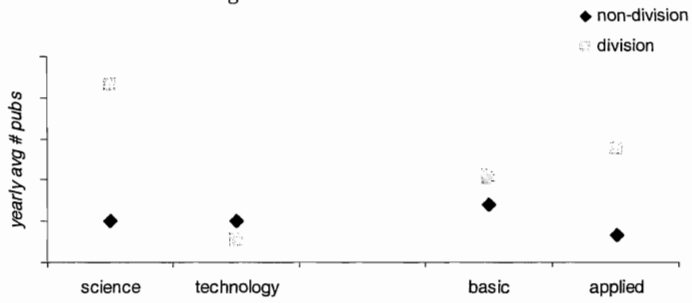


FIGURE 4 – Interaction effect between division membership and type of publications in Pharmacology

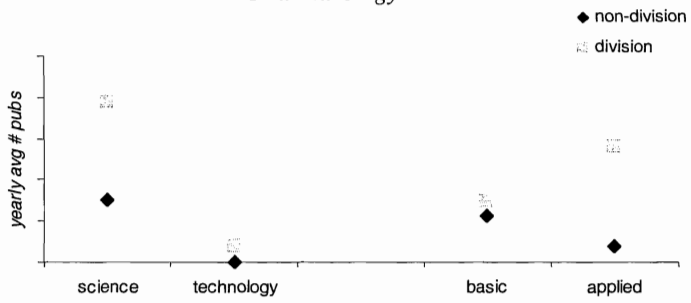


FIGURE 5 – Interaction effect between division membership and type of publications in Sciences

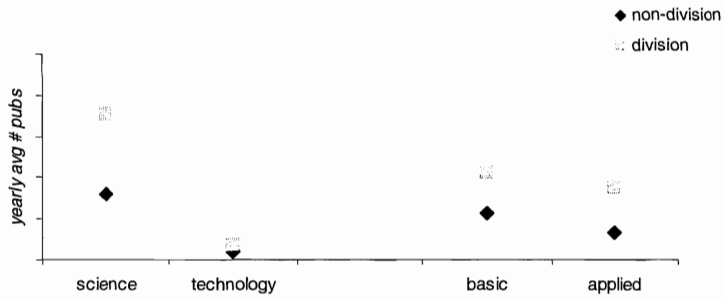


FIGURE 6 – Evolution of the differences between division and non-division members regarding number of publications (per type; 1991-1999, only applied sciences)

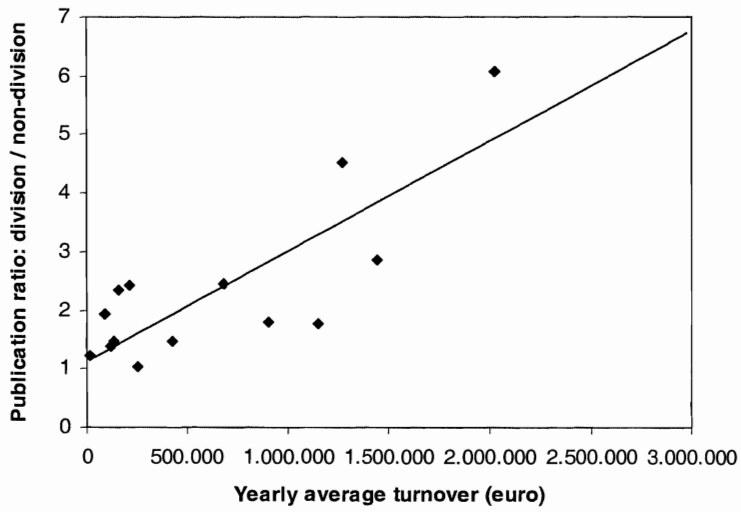


FIGURE 7 – Publication ratio (division members / non-division members) in relation to division turnover

