Combining the production and the valorization of academic research: A qualitative investigation of enacted mechanisms.


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0. Introduction

The emergence of knowledge-based societies has over the past decades spurred research on the specific role of knowledge generating institutes - like universities - in innovation systems. The notion of academic entrepreneurship has gained acceptance among communities of researchers, practitioners and policy makers (Etzkowitz et al., 1998). At the same time, this acceptance seems impregnated by a constant alertness for the tensions that may arise. Concerns are uttered in terms of shift of the academic research agenda towards industry needs, resulting in fewer investments in basic research. Furthermore, the conflicting nature of the normative principles that guide academia and business has been warned for: competitive considerations and secrecy practices seem to stand in direct opposition to the principle of free dissemination of scientific knowledge.

Empirical examinations have been conducted at several levels, touching upon the why, the who and the how of academic entrepreneurship. Access to complementary research and human resources appear main drivers for industry to engage in partnerships. Hall et al. (2000) pointed to the crucial role that universities play in contributing to basic research awareness and insight among their private sector partners (see also David et al., 1994; Rosenberg & Nelson, 1994; Zucker & Darby, 2001). At universities’ side, financial motivations are often put forward. Characteristics of technology transfer offices and other intermediary mechanisms have been studied in terms of their possible contribution to transfers between the academic and industrial spheres (e.g. see Debackere, 2000; Siegel et al., 2003). Questions have been addressed on how to design incentive schemes and contracts for (academic) scientists to get involved in valorization or commercialization of their research, while at the same time ensuring commitment to their traditional academic research mission (Cockburn et al., 1999; Jensen & Thursby, 2001; Jensen et al.,
2003; Stern, 2004). At the level of the individual researcher, career viewpoints have been taken into account (Levin & Stephan, 1991; Owen-Smith & Powell, 2004; Dietz & Bozeman, 2005; Crespi et al., 2005) and the effects of academic entrepreneurship on publication activity has been assessed in mostly output-oriented analyses (Blumenthal et al., 1996; Azoulay et al., 2004; Van Looy et al, 2004, 2006).

Notwithstanding such a diversity of viewpoints and the specificities of each analysis, the general conclusion can be drawn that a combination of scientific and entrepreneurial activities appears feasible. Several context-specific conditions and constraints need to be taken into account, but overall the feasibility of a combination seems sufficiently supported in the empirical literature. Our own previous research has illustrated this in the context of the Catholic University of Leuven. At the level of the individual professor, both involvement in contract research with industry (Van Looy et al., 2004) and involvement in technology development through patents (Van Looy et al., 2006) were associated with higher levels of scientific publications. Moreover, no evidence was found for the skewing phenomenon – i.e. a shift towards more applied publications at the expense of basic research - and the ‘advantage’ of entrepreneurial professors seemed to increase over time. Similar observations on the feasibility or even the positive effects of combining entrepreneurial to scientific activities have recently been made in several other studies (Calderini et al 2005; Gulbrandsen & Smeby, 2005; Meyer, 2006). Some professors seem to have more opportunities than others. This can be due to external conditions and own achievements, either actively pursued or obtained accidentally (Azoulay et al., 2005). Actual differences are only being made if such opportunities are also enacted. Altogether, the empirical literature remains relatively silent when it comes to unraveling the dynamics behind successful combinations of entrepreneurial and scientific activities, e.g. in terms of allocating time, dealing with conflicts of interest, ... It is in this area that we want position this contribution. Our aim is to get an in-depth and practice-informed view on how academic professors reconcile their scientific and entrepreneurial agenda.

1. Research framework

Several explanations of a positive relation between scientific and entrepreneurial performance can be put forward. A review of the literature on university-industry interactions – focusing on its antecedents, mechanisms and consequences - guided ten exploratory interviews that were conducted at the Catholic University of Leuven. These preparatory interviews served in getting a practice-informed view on the relevance of different factors that are touched upon in the literature. Hence combining insights from practice and theory led us to formulate a research framework with links to a resource-based organization view. The resource based view was developed and has been mostly adopted for business sector research (Barney, 1991). It is built around the premise that various forms of financial, physical and human resources can provide an organization with competitive advantage. As universities nowadays become more and more confronted with business issues and environments, the resource based view seems apposite for thinking about universities as well (Powers & McDougall, 2005). In our research, we take it down to the level of the individual researcher. For academic professors who perform scientifically as well as entrepreneurially, we want to offer insight into whether and how they exploit opportunities created from three types of resources: knowledge, budgets and staff (human resources). In relation to these resources, three premises are developed.
Opportunities from knowledge resources

Models of knowledge creation, diffusion and innovation have become increasingly dynamic. Basic research is known to serve purposes of application-oriented research and development, but also the opposite direction is essential in today’s circular view on innovation. Knowledge gained from application-oriented and technological activities is fed back into the basic research agenda; at times questioning basic assumptions and theorems and in some cases even urging for paradigm shifts (Kuhn, 1962). The result is a system where science and technology benefit from one another in a continuous interaction, and both frontiers are advanced through mutually supporting dynamics (Steinmuller, 1994; David et al., 1997; Pavitt, 1997). Such beneficial feedback loops between basic science and industrial application will also be taking place at the lower level of the individual researcher’s agenda: engaging in either one then benefits the activities undertaken in the other. Entrepreneurial professors may have broader access to relevant state-of-the-art, thanks to their more frequent and systematic interactions with industrial partners. This might provide food for thought and publication, allowing them to formulate and address relevant research questions. So knowledge gained from application-oriented industry interactions feeds back into the more basic scientific research agenda (Rosenberg, 1982; David et al., 1994; Foray, 2004). To the extent that fundamental research precedes commercialization activities - and if knowledge is considered as an ‘asset’ - fundamental research itself can indeed have direct ‘investment value’ for application-oriented R&D (Lacetera, 2005). Inversely, application may bring new ideas that can serve the basic research agenda, reducing problems of problem choice (Zuckerman, 1978).

Treating knowledge as an economic good as vindicated by the economics of knowledge (Foray, 2004), benefits from topic overlap between fundamental research and commercialization activities could be asserted through the presence of "economies of scope", in whichever direction the knowledge spillovers occur. In a pharmaceutical firm setting, Henderson and Cockburn (1996) identified economies of scope at the firm level, stemming from the opportunity to exploit knowledge across program boundaries. These economies of scope occur if an asset can be used in more than one application at no or marginal additional cost, or when the results of successful research in one field have positive implications for work in other fields. In an analogous way - but at the level of the individual research agenda rather than at the firm level - the exploitation of knowledge across activities may leverage the output of either activity. For such cross-activity cumulative advantage effects to take place, some degree of topic overlap is supposed between the basic scientific work and the industry-oriented applications.

Premise 1: Successful entrepreneurial professors could benefit from economies of scope through the occurrence of topic spillovers between the basic and applied research agenda.

Besides topic spillovers, reputation spillovers could reinforce leveraging effects between activities. The higher visibility and reputation that are associated to larger publication stocks would make these professors preferred partners for industry actors that are looking for cooperation with academia. The combination of such a selection effect to knowledge spillovers could explain the well-known Matthew effect: the cumulative advantage would not only take place within science (Merton, 1968a,b) but also across scientific and entrepreneurial activity (Van Looy et al, 2004).
Opportunities from financial resources

The occurrence of financial resource spillovers between industry-oriented activities and basic research activities has been advanced frequently as one of the main drivers behind increased entrepreneurialism in academia (Etzkowitz et al., 1998). Entrepreneurial activities are often said to be pursued by universities in a reaction to decreased government funding levels for basic research. This suggests that money from entrepreneurial funds would be transferred to research activities that were previously paid for by government money. Many of the concerns about distorting effects of industry funding on the university research agenda are inspired by observed shifts in budget flows at the national and systems level. At the institutional level, university management and outcomes are indeed directly affected by such funding shifts. Here, the discussion on whether increases in entrepreneurial funds are for the worst or for the best largely coincides with the broader discussion on academic entrepreneurship.

Some empirical evidence suggests the presence of opportunities that could be leveraged through financial resources, including those stemming from industry. Powers (2004) empirically showed a positive relation between federal R&D funding and technology transfer outcomes at the university level (technology licensing to existing firms). This suggests a positive effect of basic research funding spilling over to the application side\(^1\). Inversely, figure 1 (adopted from Van Looy et al., 2004) suggests that financial resources, gained from contract research with industry, could lever basic research.

\[\text{FIGURE 1 – Publication ratio in relation to division turnover} \]
\[(\text{adopted from van Looy et al., 2004)}\]

\(^1\) The effect on publication output was not considered in this particular study.
The figure maps the publication advantage of professors who are members of a contract research division, i.e. professors who are structurally involved in research contracts with industry. It is shown that their publication advantage over a control group of non-division colleagues becomes more outspoken for contract research divisions with higher turnover (Van Looy et al., 2004). This suggests a positive effect of entrepreneurial funding on basic research activities. In a questionnaire study among Norwegian professors, Gulbrandsen and Smeby (2005) also found industry funding to be strongly correlated with high publication productivity.

**Premise 2: Part of the « star phenomenon » may be explained by the opportunity to compensate for public funding decreases using entrepreneurial funds.**

The association between having access to large entrepreneurial funds and at the same time being a productive scientist may also be a selection effect: the most productive scientists could self-select into the most successful contract research divisions. However - and probably in addition to the selection effect - it is very plausible that the availability of extra financing allows for acquiring resources that benefit the basic research. Research materials, equipment and infrastructure may be made available, increasing the group’s physical capital. The total group budget is usually an indication of the scale of the research being conducted. Importantly, more financial resources immediately translate into more room for human resources: a factor which in turn could contribute to the attainment of successful multiple output profiles.

**Opportunities from human resources**

Another factor that emerged from the exploratory interviews at K.U. Leuven and from the literature is the size and composition of the research group to which the professor is associated (see e.g. Carayol & Matt, 2004; Turner & Mairesse, 2003).

Group size as such reflects the scale of the research activities. It can be suspected to be related to group budget (Crow & Bozeman, 1987), as each group member often represents a specific funding source and addition of group members is mostly indicative of successful rounds of fund acquirement. Larger groups could point to more critical mass present in a researcher’s group. If then his group members include the professor as author on most of their publications, one is inclined to think: the larger the better. Turner and Mairesse (2003) empirically showed a positive peer effect. An individual was likely to be more productive when the level of his colleagues’ productivity in the lab was high. However, they did not find a ‘size’ effect. This implies that it is not the amount of group members surrounding an individual, but rather their scientific quality which matters for individual publication performance. Recently, in a recent study on research productivity in Dutch economics and business research programs, Groot and Garcia-Valderrama (2006) found group size to be negatively related to research productivity, but positively related to research quality. They suggest that larger groups appear to have the potential to improve quality, but as groups become larger, they also experience problems in maintaining the research productivity of the research team’s members. In terms of group size, decreasing returns to scale may become apparent if the costs of managing and coordinating the group become larger than the output benefits yielded (Hackman, 1978). Clearly, throughout the literature on academic group size, mostly the impact on scientific output has been investigated and this has yielded diverse results. We are especially interested in whether and how the group can
contribute to a combined scientific and entrepreneurial output profile. Group composition seems to be a factor of crucial importance in this respect.

Gulbrandsen and Smeby (2005) found industrial funding to be associated to a highly collaborative mode of doing research. Increased collaboration was thereby not only observed with external partners, but also with colleagues in their own department. Indeed, the presence of a research group allows for more possibilities in terms of task allocation and specialization (Carayol and Matt, 2004). It has also been argued that increased industry-orientation in research coincides with an increased need for multidisciplinarity. A heterogeneous group would then be more favorable if industry-oriented activities are undertaken. Moreover, if and to the extent that basic research and industry-oriented activities would involve different role attributes (as e.g. suggested by George et al, 2006), having different persons focus on the one or the other could be instrumental in avoiding role conflict.

Premise 3: The size and composition of the research group surrounding an entrepreneurial professor play an important role in maintaining his level of scientific output.

2. Research setting and approach

Given that our aim is to go in-depth and to complement existing quantitative empirical research, a qualitative approach is adopted here. The paper reports on semi-structured interviews that were conducted with a sample of 32 professors at the École Polytechnique Fédérale de Lausanne (EPFL). Founded as an engineering school in 1853 – and becoming a federal university in 1969 – the EPFL is now a leading scientific and technological university in Switzerland. The school hosts approximately 280 professors, 2000 researchers and 6200 students (incl. postgraduates). It gathers over 250 laboratories and research groups in 7 faculties covering Basic Sciences, Engineering Sciences, Architecture, Information Sciences, Life Sciences, Humanities, and Technology Management. Research valorization, technology transfer and socio-economic contribution are an explicit part of EPFL’s mission. Mostly since the late 80’s, this strategic orientation has been institutionalized in several ways. Interfaces such as the SRI (Service des Relations Industrielles) and CAST (Centre d’Appui Scientifique et Technologique) offer support for patenting and licensing activities, contract research and start ups.

The basis for the selection of interview targets was a mapping of EPFL professors’ involvement in inventive activities (invention disclosures and/or patents), and scientific activities (publications). No a priori choice was made in terms of faculties. Table 1 presents the breakdown of our sample in faculties and their involvement in inventions.
Let it be noted that any quantitative data gathered served only the purpose of sample selection. Secondary sources were used that may not cover exhaustive outputs and data were extracted for a fixed time period. Due to their crudeness, these data do not allow for meaningful quantitative analyses. But they are surely appropriate for a comparative output mapping and they allow for the identification of professors who are successfully active in entrepreneurial (inventive) activities and who at the same time remain among the top in terms of research output. In addition to these combined profiles, some professors were selected with more 'focused' profiles, in that they were not involved in patenting activities. Table 2 presents the profile diffusion of the interviewed sample. Inventors and non-inventors are broken down in three categories of publication output: high, medium and low. These categories represent the third percentiles of publication output of all EPFL professors\(^2\) (N=286). Of this total population, 18 professors are in the 'high' percentile, with over 45 publications for the period under consideration. 42 professors are in the 'medium' percentile, with between 20 and 45 publications. The remaining 226 professors are in the 'low' percentile, with less than 20 publications. This reflects the well-known skewed distribution of publication-output; we interviewed 50% of the ‘star’ scientists in the upper percentile.

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**TABLE 1 – Sample of interview respondents**

<table>
<thead>
<tr>
<th></th>
<th>Inventors(^{(1)})</th>
<th>Non-inventors(^{(1)})</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Sciences</td>
<td>9</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Basic Sciences</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Life Sciences</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Information Sciences</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Architecture</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>9</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

\(^{(1)}\) With 'inventors' we refer to persons appearing as such in the Micropatents database (1971 – present). All of these except for 2 also had one or more invention disclosure at EPFL’s TTO. There were also 2 non-inventors who nonetheless had one or more inventions disclosed at the TTO.

**TABLE 2 – Publication output of interview respondents**

<table>
<thead>
<tr>
<th>Publication output</th>
<th>Inventors</th>
<th>Non-inventors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Medium</td>
<td>8</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Low</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>9</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

The focus of this study is primarily on those professors who are successfully involved in entrepreneurial activities, and who at the same time maintain a satisfactory publication performance. Therefore over 70% of the 32 respondents are inventors and over 70% have a medium to high publication performance. It should be noted that generally, also non-inventors are involved in some kind of industry-oriented activities such as contract research with industry, or even startup involvement: academic entrepreneurialism goes beyond academic patenting. Professors were interviewed on the occurrence of topic spillovers between their scientific and entrepreneurial activities, their use of different funding sources and the role of the

\(^2\) Database of WoS publications with EPFL affiliation; for the years 2000-2004.
research group. The open-endedness of the interview protocol left room for other factors to be touched upon. In what follows, for each of the three considered factors, we extract the general picture that emerges from our respondents’ stories. To that we add some figures on the incidence of statements, thereby also providing insight in statements that are less frequent and that seem to deviate from the main story.

3. Results

3.1. Opportunities from knowledge resources: Application as a byproduct of understanding

3.1.1. Research agenda

A high degree of topic overlap is indicated by most respondents. Rather than pointing to a dynamic of ‘spillovers’ however, such overlap is often mentioned as being intrinsic to the conduct of research: “understanding presupposes applying and applying presupposes understanding”. Going by Stokes’ (1997) categorization of research, these respondents strongly adhere to Pasteur’s quadrant. They prioritize the conduct of basic science but they couple this very tightly to inspiration from possible uses and applications. Many respondents did not even acquiesce in the distinction between scientific and valorization activities - thereby diluting even the relevance or validity of ‘multitasking’ conceptualizations. Topic overlap is hard to capture because essentially, it is a dynamic of continuous feedback loops between fundamental and application-oriented research. When asked specifically for pinpointing some topic overlaps between patents and publications, respondents clearly stated that everything that is patented is also published, and that both activities – publications and patent applications - are consequences of one and the same research project. The basic research agenda is primordial, and its development gets the highest priority by far. This research agenda is the common nominator of all outputs, with publications covering the whole spectrum. Patents or development of specific industry-applications then represent a subdivision of all the knowledge created.

Table 3 shows how our respondents judged topic overlap in their basic science on the one hand and their industry-oriented activities on the other hand. Their views on this reflect their views on the relation between basic and applied research.

**TABLE 3 – Respondents’ view on topic overlap between basic and applied activities**

<table>
<thead>
<tr>
<th>Topic Description</th>
<th>Inventors</th>
<th>Non-inventors(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Applications as byproducts (or even joint products) of basic research</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>(2) Feedback loops between basic research and applications</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>(3) Keep basic and applied research sufficiently separated</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

(*) For two respondents, this was unclear. They are not in the table.

As said earlier, a high topic overlap is generally expressed, especially among the inventors: over half of them are in the upper group (1). Persons in this group are reserved about the distinction between basic and applied. In its most extreme manifestation, a few respondents expressed sheer denial of this distinction. They
would consider publications and applications as ‘joint products’. Most respondents are more moderate: they refer to applications (or patents) as ‘byproducts’ of their primordial activity which is basic research. The second group (2) of respondents appears more tolerant to the distinction between basic and applied and describe topic overlap between activities in terms of continuous feedback loops from basic to applied and vice versa. A minor share of respondents still argued for a separation between basic and applied activities. Their arguments are various: the academic setting still imposing taboos on application-driven research, collaboration with industry is merely a way of getting access to specific resources (cf. supra), difficulties to balance short term application and long term fundamental research.

Rather than categories, these three groups should be considered as representing a continuum of perceived alignment between purely scientific and application-oriented activities, going from high to low. Most professors are at the high end of this continuum. The obviousness with which they state this high overlap creates the impression that research valorization spontaneously flows from knowledge creation. This would mute allegations on tensions and problems possibly arising from the combination of fundamental research activities on the one hand and more application- or industry oriented activities on the other hand. Of course, digging deeper into what was being said reveals clues for qualifying the practical implementation of the abovementioned conceptualization. The flow from knowledge creation (‘understanding’) to knowledge valorization (‘applying’) is not necessarily a spontaneous one. Something more is needed to push towards development and the ‘use’ of research. Open-mindedness and an a priori orientation towards or sensitivity for valorization opportunities seem crucial factors here. Several researchers expressed a more or less proactive stance towards the development of applications, which seems a condition sine qua non for getting things out on the market.

Professor 5 < Engineering Sciences: “For me, I am in academia, publication has to be my number 1 priority. If I can’t publish well, I don’t get good students, I don’t get recognition, I don’t get reputation. So publication has to be number 1. Then, to put out patents: if it happens, it happens. It is not that we are driving towards it. I don’t see it as something that we would plan for the next two years. But you have to be open-minded enough to know when to do it.”

Professor 6 < Engineering Sciences: “For us, publications are most important. But it’s clear that the question of patenting is in the room. So if we have a publication and we see some potential, then we check with our patent group here.”

Professor 7 < Engineering Sciences: “I am not oriented towards patenting. I am oriented towards not losing an opportunity to patent.”

This implies that, at the science side and in terms of the academic research agenda, no tensions or problems are experienced with an entrepreneurial orientation. The opposite is even expressed: scientific activities benefit from an orientation towards

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3 The terms ‘joint products’ and ‘byproducts’ were not as such used by the respondents themselves. We refer to their definition in accounting. Joint products are two products that are simultaneously yielded from one shared cost and they have a comparably high (sales) value. Byproducts from their side are produced along with a ‘main’ product. The latter constitutes the major portion of the total (sales) value. Byproducts have a considerably lower (sales) value than these main products. We can use these terms to think about basic research (publications) and applications (e.g. patents), by using ‘perceived value to the academic professor’ instead of ‘sales value’.
applications\textsuperscript{4}. With regard to alleged secrecy issues when wanting to publish something that may be patented, most respondents indicated that their patents and publications are developed in parallel, with difficulties rarely occurring. At most, publications may be delayed for a few months if a patent will be filed. But normally, the patent application is finished by the time the publication manuscript has gone through the review process and before final submission of the publication. As such, allegations on industry-orientation (negatively) influencing the academic research agenda do not find support, at least not within the context of this study.

3.1.2. Interaction with the industry partners

Moving beyond the conduct of science and the maintenance of the academic research agenda, some qualification is in place regarding what actually happens when an industry partner comes in, or when knowledge is being transferred towards industrial partners. Respondents, when explicitly asked about possible tensions at this point, claim that these can easily be escaped. They prefer to talk of ‘constraints’ rather than ‘tensions’ and say that difficulties can be avoided if you are aware of these constraints from the very start. Some anecdotes show how learning what you should and cannot do sometimes had to be done the hard way.

Professor 10 < Engineering Sciences, speaking of when they were about to develop a - now very successful - startup "... We didn't do things right, we made mistakes in this specific case. In the beginning, before we thought of doing the startup, we wanted to partner up as a university team with a big company. That's why we published a lot. Then we saw that this partnership was going nowhere... and we decided to go for the startup. ... So we have learnt the hard way: we do not publish what we have not filed."

Professor 5 < Engineering Sciences, when asked about possibly negative effects of secrecy norms in industry: "It has happened. We had one case with [company] where it has been detrimental. We had a brilliant postdoc. For two years, he had been refused to publish. And that is really a pity. ... He was a brilliant guy. A nice guy also, he accepted this restriction. But he is looking for a professorship now ... so he needs publications."

Anecdotes like these point to some difficulties that may occur in practice at the point where there is industry linkage. Possible tensions, if any, are mostly incurred by ‘inexperienced’ researchers. Experienced professors know how to prevent them, by adopting one or more of the following principles:

- **Selectiveness**: selecting industry partners and projects for cooperation only if they can somehow align to the academic environment.
- **Contract clarity**: being very clear when formulating contracts with industry partners; especially for guaranteeing the possibility of publishing.
- **Foresight**: knowing what may be valuable for (commercial) development later on; and not going public with concepts or results on which a patent may be filed later on.

\textsuperscript{4} Interestingly, several researchers pointed out that the worst enemy of the basic research agenda is the science system itself. Excessive focus on international visibility makes scientists lock themselves in ‘fashionable’ topics, possibly at the cost of more interesting research tracks. On the other hand, being too advanced is not rewarded by the system as peers are not ready yet to absorb and assure some follow-up.
Synthesizing the respondents’ stories until now, it appears that an entrepreneurial orientation does not hamper the creation and maintenance of an academic research agenda. Following their paradigm, this agenda is even said to benefit from use-inspired feedback loops. Some – be it avoidable - conflicts can however relate to the management of research outputs at the point where the entrepreneurial orientation is being enacted: i.e. when the link with industry is put into practice or when knowledge is actually being transferred.

Further elaboration on how problems pose themselves and on the relevance of ways to avoid them, requires consideration of the context in which academic and industry partner are linked. Assembling these contexts reveals a highly diversified picture, within and across respondents. From a synopsis of the different stories, three scenarios emerge, that are schematized in figures 2a, 2b and 2c. The industry linkage sometimes consists of a sequence of different of these patterns. The distinction between 'industry pull' scenarios and a 'research push' scenario is based on which of the partners initiates or motivates the interaction. In the research push scenario (2c), the research leads to some result that could be further developed and valorized. Several avenues can be taken at this point: the academic partner can create a startup based on the development, the academic partner can take a patent and license it to industry partners, or the research result can be a starting point for a follow up project with an interested industry partner. The 'industry pull' scenarios are distinguished by whether or not the research done within the interaction is aimed at a specific predefined goal. Scenario (2a) represents a traditional research contract, in which the academic partner works around some specified problem or question, posed by the industry partner. Mostly, some specified output is to be delivered at some point in time upon which the partners have agreed. In scenario (2b), the academic researcher pursues his research agenda, but allows some industry partner to support and scout the research being done. This is mostly done against some payment, and it appears that the industry partner is mostly a large firm that can afford investing in such research scouting in one or more research institutions. Specific about this scenario is that it does not involve a specific result, as the industry partner does not specify contractually what it is looking for.

*FIGURE 2 – Scenarios of university-industry linkage*

- academic research
- industry involvement
- some research result that may be worth development

(2a) Industry pull - defined research contracts / mandates – working towards a fixed and predefined goal.

(2b) Industry pull - research scouting by the industry partner – no fixed or predefined goal
(2c) Research push - research result which is worth commercial development, brought out onto the market, industry partner only comes in after the research has been done.

These different scenarios are not meant to provide an exhaustive mapping of collaboration modes. They represent patterns that can be discerned in our respondents’ stories and their relevance lies in outlining case-specific dynamics to be taken into account (for a well-documented similar exercise in the plant breeding sector, see Joly & Mangematin, 1996). The following stylized arguments show how this can be done.

To start with, it could be argued that, if any influence of industry involvement on agenda setting is present, it would most likely occur under scenario (2a). Here, the research being done on behalf of the industry partner runs in parallel to the ‘normal’ line of research being done on behalf of academia, where it may represent some side track. In scenario (2c), industry involvement and research valorization only start at the end of the ‘normal’ research being done. In scenario (2b), the interaction is framed in such a way that the industry partner observes, without steering. There is no specific goal towards which the research should be aimed besides the research agenda already in place. Per definition, the academic research in this scenario should be pursued as if there was no industry partner. It is clear that the timing and the directions of the feedback loops, as well as the consequent topic overlaps, are to be considered in the light of the scenario in which the university-industry interaction is embedded. In addition, the relevance of ways for dealing with possible tensions differs according to the interaction mode. Recall that constraints to be taken into account were mostly related to managing outputs at the point where the industry orientation is being enacted. These scenarios represent the contexts of this enactment. ‘Selectivity’, in an industry pull scenario, essentially means saying yes or no to projects. This decision appears to have a bigger influence on the research under scenario (2a) than under scenario (2b). In the former, a subdivision of the academic research is directly being ‘steered’ by the industry partner. In the latter, the industry partner is a mere supporter and observer. In the research push scenario (2c), selectivity really means choosing a partner to develop something that came out of the research. Its relevance depends on the avenue chosen. If a startup avenue is chosen, the industry partner is created rather than chosen. If the licensing avenue is chosen, it often seems that the fact of finding someone willing to ‘buy’ the technology seems more important than being selective in deciding on who gets to buy it\(^5\). However, to the extent that future cooperation is needed with the licensee for further development of the invention, selectivity again becomes relevant. In such cases, an avenue is chosen that leads back to scenario (2a). Opportunities for

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\(^5\) A patent application is dropped by the school if after a certain period of time (approximately 1 year), no licensing partner has been found.
success in scenario (2c) are most importantly defined, not by selectivity, but by the ability to foresee some valorization potential. Some foresight of the academic partner is even a necessary condition for scenario (2c) to occur. In the two other scenarios, industry’s foresight may be sufficient as it can to some extent substitute for a lack of foresight at the academic side. As for the relevance of contract clarity, it is high in all three scenarios. The type of contracts is of course fully contingent on the cooperation mode. But a clause guaranteeing the possibility to publish for the academic partner is mostly important in scenario (2a). Related to this, and mostly important in scenario (2b) is an agreement that no part of the research being conducted can be made exclusive for use of the scouting industry partner. Scenario (2c) often revolves around some licensing contract; these are mostly relatively standardized. Many respondents indicate the welcome support of the technology transfer office in defining and following up contractual agreements.

Relating these contentions back to what was said in the interviews, table 4 shows the frequency of associations between ways to deal with tensions and the specific scenarios.6

Table 4 – A synopsis of stories: frequencies of association between scenarios of university-industry linkage and ways to avoid difficulties with it

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2a (industry pull – predefined objective)</th>
<th>2b (industry pull – scouting without objective)</th>
<th>2c (research push)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selectivity</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Contract Clarity</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Foresight</td>
<td>/</td>
<td>/</td>
<td>10</td>
</tr>
</tbody>
</table>

In this overview, the research push scenario (2c) comes out as most prominent; an observation which is in line with the paradigm expressed and in which developments are byproducts of curiosity-driven research. Scenario (2a) is also mentioned frequently. More than with scenario (2c) however, the interview protocol explicitly inquired about this type of scenario. Scenario (2b) is less cited. As for ways to deal with difficulties that may arise from industry-involvement, in general, ‘selectivity’ is mostly touched upon. ‘Foresight’ is also mentioned quite frequently. In line with the argumentation above, foresight is exclusively mentioned in association to the research push scenario. ‘Selectivity’ seems most relevant in industry pull scenarios with a predefined goal (2a), but has also been mentioned in the research push scenario. ‘Contract clarity’ is mentioned to a somewhat lesser extent, but seems most relevant in scenario (2a).

To conclude, the stories reveal that an entrepreneurial orientation should not hamper the objectives of the academic research agenda. Positive influences are even touched upon through mutual feedback loops between understanding and applying. Some conflicts can however relate to the management of research outputs, at the point where the link with university-industry link is put into practice. However,

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6 It should be noted here that these categories and the matrix structure have been developed a posteriori, at the moment of data analysis and synthesis of the stories told. So interviewees were not systematically asked to classify the cases of which they spoke.
experienced researchers indicate ways for avoiding such conflicts, three important ones being selectivity, contract clarity and foresight. The topic-wise harmonization between basic research agenda and industry-oriented activities, as well as the relevance of ways for dealing with possible conflicts are dependent on the context in which the interaction between the academic and industrial partner is framed.

3.2. Organizing for balance: harmonizing financial and human capital

3.2.1. The role of financial resources

A first thing to note when considering funding sources at EPFL is that a relatively large amount of funding is provided by the school. Laboratories enjoy a comfortable position in terms of basic funding and research infrastructure. This implies that, at least within our sample but mostly throughout the whole school, no ‘poor’ labs were found that need to tie the knots together. The argument that involvement in industry contacts would be motivated by the access it provides to capital resources therefore seems less relevant, at least in the context of EPFL. The lack of financial dependence of industry partners also implies that in research contacts with industry, the academic partner has a relatively strong negotiation position. This could be relevant in setting clear contractual agreements, which was in the previous section shown to be a way for handling tensions.

Resource dependence theory (Pfeffer & Salacnik, 1978) postulates that organizations seek to reduce their dependence on resource flows over which they have little or no control. This often implies consolidating internal sources of support, which allows reducing external resources. Although possibly useful for considering university budgets (see e.g. Powers, 2004), the practices observed at the level of the individual professor in our sample shows some limits of this organizational theory in the academic setting under study. Notwithstanding these professors’ relatively comfortable situation with regard to internal funding, most respondents indicate substantial effort and time being spent on assembling the group’s ‘external’ budget portfolio. Raising funds - i.e. mostly writing and submitting project proposals, and in some cases finding possible partners to team up with - is by some said to be a relatively unsatisfying and scientifically non-rewarding activity. Laboratories’ budgets consist of a portfolio of several projects, funded by different sources. The exact composition of this portfolio differs quite a bit among respondents. Generally though, it is some combination of the following funding sources – in addition to the base funding that is provided by the school.

1) Swiss government money for basic research that is provided through funds of the Swiss National Science Foundation (FNS). Basic research projects are funded through the payment of mostly salaries for researchers (e.g. funding a PhD student over a time period of approximately three years). Some indication of the usefulness of the research is needed, but there is no requirement in terms of including industry partners.

2) Swiss government money for application-oriented research projects, provided through funding of the Innovation Promotion Agency of the Federal Office for Professional Education and Technology. The aim of this office is ‘to put the scientific potential of academic institutions to better business use’. It provides funding for entrepreneurially oriented R&D projects and business ideas with high market potential. Involvement of one or more industry partners is a necessary
requirement for getting CTI funds. In these projects, CTI pays for the researchers’ salaries and the industrial partners finance their own expenditures and make a cash contribution to the research. So part of the funding for the academic partner comes from industry.

3) European money for projects executed in one of the research programs funded by the European Commission. Depending on the programs, these projects can be basic or applied research. In most cases, the project is to be executed in some network with European partners. These can be academic partners, but often also, industry partners are required.

4) Industry funds can be acquired through the execution of research or consultancy contracts. Involvement of the school’s technology transfer office implies that an overhead is being paid to the school. License income is shared by the school, the lab and the inventors.

The proportion of direct industry money is by most respondents said to be very minor. In addition, the chance of earning a lot of money from license revenues is very small. Indeed, the motivation for patenting is not a financial one. Contract research with industry partners is often framed within a CTI or EU program; so industry money is not directly flowing into the lab. However, the fact that direct industry money is a small proportion of the total budget, and the absence of financial dependence of industry partners due to the funding provided by the school, does not imply a lack of cooperation with industry.

Table 5 gives an overview of respondent’s view on whether industry-money fills a gap caused by decreases in more traditional forms of – basic research – funding.

Table 5 – Respondents’ view on whether industry funding fills gaps in other – basic research – funding

<table>
<thead>
<tr>
<th></th>
<th>Inventors</th>
<th>Non-inventors</th>
<th>Total(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>No</td>
<td>18</td>
<td>2</td>
<td>20</td>
</tr>
</tbody>
</table>

(*)For six respondents, it was unclear.

The fact that industry money – whether direct or earned through EU or CTI funds – would replace traditional funding sources is confirmed by only 6 respondents. The other ones argue that this is untrue, at least in their case: they have a very comfortable position in terms of funding. Essentially it seems there are no critical gaps to be filled. Besides, for patenting and licensing, respondents agree that it does not pay off. So even if there would be a gap to fill, getting patents is not the way to achieve it. Nevertheless, industry-originated money, earned mostly through contract research then, serves another important function. Over one third of the respondents indicate that it complements government (FNS) money for basic research. A tradeoff is to be made in assembling the funding portfolio. Basic research funds give a lot of freedom to do exploratory and innovative research, allowing to push the science frontier in a curiosity-driven way by working on new ideas. In contrast to this freedom in research content however, budget rigidity makes that outside the salaries covered, no extra expenses can be accounted for such as traveling, buying equipment, hiring a temporary employee,… Application-oriented projects with industrial partners from their side usually provide the researchers with more freedom and flexibility in budgeting and allocating resources. They therefore allow for the
creation of some pool of funds that can be used in a flexible manner for things like traveling, paying temporary employees etc... However, because industry partners are included, these projects are often stricter in terms of research content and project organization. Collaboration with a priori defined partners implies that the research direction and objectives are set at the start, clearly defined deliverables are due at agreed upon deadlines. This strictness often also implies a heavier administrative burden.

As such, our respondents indicate that industry money – direct or indirect – is used, not to fill gaps and substitute for decreases in other funding sources, but as a complement of basic research funding. This result seems at odds with what Boumahdi et al. (2003) found in a panel data analysis of French research laboratories: contractual public funding appeared to crowd out simultaneous private funding, pointing in the direction of a substitution effect. Most respondents in our sample seem to consider them as complements and try to develop a balanced budget portfolio. Focusing on one source would either hamper some degree of budget flexibility, or else define the project organization and boundaries of the research content too strictly.

Professor 3 < Basic Sciences: "Basic money is very rigid money. Funds from application-oriented projects allow one to be flexible, to buy some extra equipment, to go to conferences,... It is the money that basically puts the oil in the system and smoothens it."

Professor 8 < Engineering Sciences "Money from applied project can serve as a kind of cement, for holding together the fundamental bricks that represent basic research funding."

There is a direct link between the group budget and the amount of persons employed in the group. Moreover, the heterogeneity in the group may or may not reflect heterogeneity in funding sources. Like this, budget can indirectly influence productivity through human resources. Group size and composition effects will therefore be discussed in the next section.

3.2.2. The role of human resources

Much research has been done on the effect of group size on research productivity. Not many studies explicitly take into account scientific and entrepreneurial outputs. An exception is the work by Carayol and Matt (2003), who studied the effect of laboratory-level characteristics on publication and patent output. Overall however, empirical results appear at points contrasting. Rather than looking for a single truth about the effect of group size and composition on outputs, our aim here is to see whether and how successful professors consider the research group surrounding them as conducive to fulfilling their entrepreneurial and scientific agenda. Questions in this block relate to how and why their research groups were composed the way they were, focusing mainly on the role of PhD students and senior researchers.

The number of PhD’s is an important parameter relating to the scale of the group’s research activities. Optimal group size is said to be between 5 and 10 PhD students. To the extent that PhD’s are regarded as outputs, this size keeps the research agenda focused and it allows for a smooth follow-up and quality control of their projects. From an input point of view, having additional PhD students beyond this threshold implies more fund raising needs, with the risk of losing focus. As for their
role in the entrepreneurial agenda, respondents have different opinions on whether or not to involve PhD students in the more applied, industry-related projects. Most professors studied deliberately involve PhD students in industry-oriented projects, preparing them for a future career in industry and allowing for an exploitation of synergies between basic research and industry-applications also at the PhD level. About one third of the respondents from their side try to avoid having PhD students on industry-funded projects or on projects executed on behalf of an industry partner. A philosophy behind this is that PhD projects should be executed with an open-minded vision and independent of any deadline or predefined objective. According to these professors, involving PhD’s in industry projects imposes risks: deadlines may not be made, but mostly also the risk that the project eventually turns out to be a dead-end, and that it is not sufficiently intellectually rewarding. PhD projects are therefore largely funded by basic research funding. Funding for applied projects goes to senior researchers and postdocs who execute these projects; and part of this money is often kept in a reserve pool for flexible spending purposes (cf. supra).

An important role is often assumed by senior researchers and permanent staff. In comparison to PhD students, who mostly move out after finishing their projects, permanent staff represent a more stable layer of critical mass. They appear best positioned to assert some continuity in the basic research agenda. Moreover, to the extent that PhD students are not involved in application-oriented work with industrial partners, the senior researchers (and postdocs) often execute these projects. With this double function in the research group, these senior researchers seem to play a pivotal role in combining and balancing basic research activities with more applied industry-oriented activities. Any lack of a sufficient layer of senior researchers seems mostly due to the fact that their position – one of being a senior researcher but not a professor - is not easily recognized. PhD students from their side represent a more volatile but very essential human resource. Their mobility constitutes an important channel for valorizing research and linking up with industry. For one thing, many of the startup activities are initialized because of PhD students who want to further develop and commercialize research results obtained in their project (see also Zellner, 2005). In addition, PhD students moving out to go and work in industry leave traces that in later stages may become the paths for cooperative projects between the lab from which the PhD students originates and the industry in which he/she is employed later on. The observation on the complementary roles of permanent and non-permanent researchers is in line with what Carayol and Matt (2004) found in their analysis of the research productivity of French laboratories.

These results support our third premise in that a research group of limited size and with role heterogeneity appears most conducive for combining an entrepreneurial and a scientific agenda.

4. Conclusions and future research directions

Notwithstanding the diversity of stories behind similar output profiles – in terms of combining publications and involvement in inventions and patents – a synthesis allows to highlight some relevant dynamics behind these output profiles.

Some remarks are in place regarding the entrepreneurial phenomenon in the academic environment studied. Increasingly, entrepreneurial characteristics are projected on academia and its members. This is of course justified: the addition of a socio-economic contribution to the academic mission cannot be denied and has had a
significant influence on the way academic research is being performed and increasingly valorized. In the selection of the interview cases, a distinction was made between inventors and non-inventors and we focused largely on the dynamics of inventor’s output profiles. Nevertheless, the interviews with the non-inventors revealed all but two of them to be involved in industry-oriented activities. It appears difficult to find non-entrepreneurial professors, especially in the faculties considered here. Reassuringly, and in line with what has been shown in several quantitative studies, this qualitative study shows that no fading of the traditional missions is implied. All interviewees expressed a deeply-rooted sense of research and education as their main missions. It even seems that the addition of an entrepreneurial mission has again highlighted these traditional missions, maybe because the danger of neglecting them becomes more pertinent. This was also articulated when they were asked about the main drivers of their involvement in entrepreneurial activities. Curiosity, “getting things out”, satisfaction from seeing research results being put into practice and feedback loops flowing back into the basic research agenda are all drivers that are anchored in or at least very closely tied to these the traditional academic research mission. In addition, transferring knowledge and leaving some legacy were deemed important and many professors expressed a strong social responsibility, wanting to ‘give something back to the taxpayer’ by creating jobs and delivering educated people to society.

The observation that this compound mission is successfully translated into combined output profiles – at least for our sample of respondents – makes us return to the three premises on the role of topic spillovers, spillovers of financial resources and human capital in achieving this output. In the context of this study, the first and third premises found support.

Firstly, topic spillovers are referred to as continuous feedback loops between the activity of ‘understanding’ a phenomenon and ‘applying’ it in practice. The paradigm by which most of our respondents conduct science essentially unites these activities of creating knowledge and valorizing it: most of them do not even consider themselves as ‘combining’ separate things. A curiosity driven basic research agenda is said to be the common nominator out of which publications flow, as well as byproducts that can be further developed or valorized through some transfer to industry. Being able to discern and respond to opportunities for further development requires an open state-of-mind, but in most cases, respondents indicate that all their activities are anchored in the existing research agenda and no separate topic tracks or side branches are created. To the extent that one common knowledge base indeed yields outputs in several fields of activity, there are economies of scope to be exploited in the combination of scientific and valorization activities. In practice however, the tightness of connection to the basic research agenda and the extent to which valorization requires no additional effort, depend on the scenario under which the academic and industrial partner interact. A professor appearing as an inventor on a patent for example, can be an outcome of very different scenarios in which possible tensions and ways of dealing with them are not equally relevant. Clearly, in the academic context, a patent is not an aim in itself in that it would bring in money or secure any competitive advantage, as it does in industry. Academic patents are a vehicle towards getting - useful - knowledge into practice. Consideration of the different scenarios in which this takes place is needed when analyzing academic entrepreneurialism.

Secondly, resource spillovers – in the sense of industry money substituting for decreased government money – do not appear crucial in coming to combined output
profiles. Direct industry money represents a minor, if some, portion of the budget. This may be very context specific: researchers at EPFL enjoy very good base funding and financial conditions; they can avoid any financial dependence on industry partners. Industry money is mostly acquired indirectly through government projects funding application oriented research, requiring involvement of one or more industry partners. Rather than substituting for it, industry money has an important function in complementing basic research funding, as it provides more flexibility in allocation of the acquired budget to things other than salaries. Generally, involvement in industry-oriented valorization activities is not at all said to be motivated by financial reasons.

Thirdly, the scale of the research activities is largely defined by the number of PhD students. Optimal size is limited, as the amount of effort required for finding funds, as well as coordinating and securing research quality increases with the number of PhD students, without any economies of scale. Senior researchers or permanent staff can represent a more stable layer of human capital, beneficial to maintaining some continuity. The higher mobility of PhD students from their side makes them adequate channels in which transfers to industry and applications of research results can be embodied.

In summary, it seems that the paradigmatic flows between understanding and applying are the main drivers behind blending knowledge production and valorization. Organizing the activities through optimization and harmonization of staffing and funding portfolios is conditional on this more fundamental factor. Resource spillovers are not so much mentioned as an ‘enabling’ factor; but funding sources from industry are a complement to the more strictly budgeted basic funds. Human capital, apart from defining the scale of the research activities, can afterwards be an important factor embodying links between research and practice. Organizing the research essentially means optimizing funding and staffing conditions, accounting also for the interplay between both. Professors in academia enjoy considerable degrees of freedom in this. This plays a non-negligible role in successful accomplishment of outputs related to knowledge production and valorization. According to the respondents’ stories, however, this should in no way be considered a sufficient condition. A successful combination between knowledge production and valorization seems to be achieved in first instance through the benefits of the paradigm by which research is conducted. The success of any organizational arrangement appears fully conditional on this more fundamental prerequisite.

The context-specificity of these observations and their exploratory and qualitative character, immediately suggest several paths for further research. Some of the views expressed here will be specific to the EPFL context and more broadly, the Swiss context. Moving beyond institutional and eventually national boundaries is likely to result in other dynamics or other focuses. Furthermore, quantitative data and analyses can complement this study and could serve in verifying some hypotheses that could be formulated from these observations.
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scientists.” Paper presented at the 2006 Academy of Management Annual Meeting, Atlanta, Georgia, US.


