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

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Introduction: Academic entrepreneurship

The emergence of knowledge-based societies over the past decades has spurred research on the specific role of 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 about shifts 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 would stand in direct opposition to the principle of free dissemination of scientific knowledge (Dasgupta and David, 1987; Florida and Cohen, 1999; Geuna, 1999; Noble, 1977).

Empirical examinations have been conducted at several levels, resulting in a vast literature on the nature of academic entrepreneurship. Abstracting from the diversity of viewpoints and the specificities of each analysis, one can assert that a combination of scientific and entrepreneurial activities seems feasible in academia. Previous research illustrated this in the setting of the Catholic University of Leuven (Belgium). At the level of the individual professor, involvement in contract research with industry (Van Looy et al., 2004) and involvement in patent activity (Van Looy et al., 2006) were associated with more scientific publications. Moreover, no evidence was found for a trend towards more applied publications at the expense of basic research. Similar observations on the feasibility or even the positive effects of combining entrepreneurial and scientific activities have recently been made in several other studies. Gulbrandsen and Smeby (2005), in a survey among Norwegian professors, found that industry funding was positively related to publication productivity. Yet they found no positive relation between publication performance and entrepreneurial commercial 'outputs', such as patents and spin-off companies. Breschi et al. (2005) analyzed patent activity of Italian academics in relation to their publication behavior. They observed no major trade-off between patenting and publishing; neither did they find evidence of a skewing effect. More productive professors were even more likely to sign for a patent, again signaling a positive relation between both activities.

Their results also suggest that trade-offs in terms of publication delays can be avoided: higher than average publications in one year immediately led to higher probability of patenting in the following year. In another study on Italian scientists, Calderini et al. (2005) also found patenting to be predicted by the number and by the quality of preceding publications. The effect of publication quantity was stronger than that of quality. However, when considering quantity and quality together, it appeared that those scientists publishing a lot ánd in highly rated journal are at low risk to patent. The authors suggest that industry may seek cooperation with the most proactive researchers but not necessarily with the most scientifically eminent ones. Azoulay et al. (2006), in their panel study on life scientists, observed that patenting has a positive effect on the rate of publication, but no effect on the quality of these publications. Meyer (2006) from his side did find a positive relation with publication quality. Drawing on a dataset of publications and patents in the field of nanotechnology, he found patenting scientists to outperform their non-inventing peers in publication counts and citation frequency.

Hence, notwithstanding some contextual qualifications, the feasibility of a combination appears sufficiently supported in the empirical literature. The 'star scientist' effect might play an important role here. Professors enjoying a strong academic reputation are highly visible not only within their scientific community, but also to industry actors that are looking for cooperation with academia. This results in the well-known Matthew effect, whereby the cumulative advantage not only takes place within science (Merton, 1968 a,b) but also across scientific and entrepreneurial activity (Van Looy et al, 2004). At the same time, the empirical literature remains rather silent on the dynamics behind successful combinations of entrepreneurial and scientific activities. It is at this level that we want to contribute, by providing an in-depth and practice-informed view on how professors reconcile their scientific and entrepreneurial agenda.

Combining scientific and entrepreneurial activities: a qualitative inquiry

The qualitative approach adopted allows for an in-depth exploration of dynamics at the level of the individual professor. The evidence revealed here builds on interviews with entrepreneurial professors at the Ecole Polytechnique Fédérale de Lausanne (Switzerland). 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 (including postgraduates). It gathers over 250 laboratories and research groups in seven 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 1980s, 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 startups.

To uncover the dynamics behind their successful combination of scientific and entrepreneurial activities, interviews were conducted with a sample of 32 professors. The selection of interviewees was based on a mapping of EPFL professors' publications and their involvement in invention disclosures and patents[i]. We selected professors who are active in entrepreneurial activities and who are at the same time prolific publishers. No a priori choice was made in terms of faculties. We also added professors a few professors who were not involved in patent activities, in order to assess to what extent opinions are inventor specific. Table 1 presents the breakdown of our sample in faculties and their involvement in inventions. Table 2 presents the breakdown of the sample in three publication output categories[ii].

Table 1 – Breakdown of sample in faculties and inventorship

	Inventors[(1)]	Non-inventors[(1)]	Total
Engineering Sciences	9	3	12
Basic Sciences	6	4	10
Life Sciences	5	1	6
Information Sciences	2	1	3
Architecture	1	0	1
Total	23	9	32

(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. Two non-inventors had one or more inventions disclosed at the TTO.

Table 2 – Breakdown of sample in publication output[iv]

Publication output	Inventors	Non-inventors	Total
High (> 45 pubs; n = 18)	8	1	9
Medium (20-45 pubs; n = 42)	8	5	13
Low (< 20 pubs; n = 226)	7	3	10
Total	23	9	32

Our exploration focuses primarily on professors who are successfully involved in entrepreneurial activities and who at the same time maintain a satisfactory publication level. Therefore over 70 percent of the respondents are inventors[iii] and over 70 percent have a medium to high publication performance.

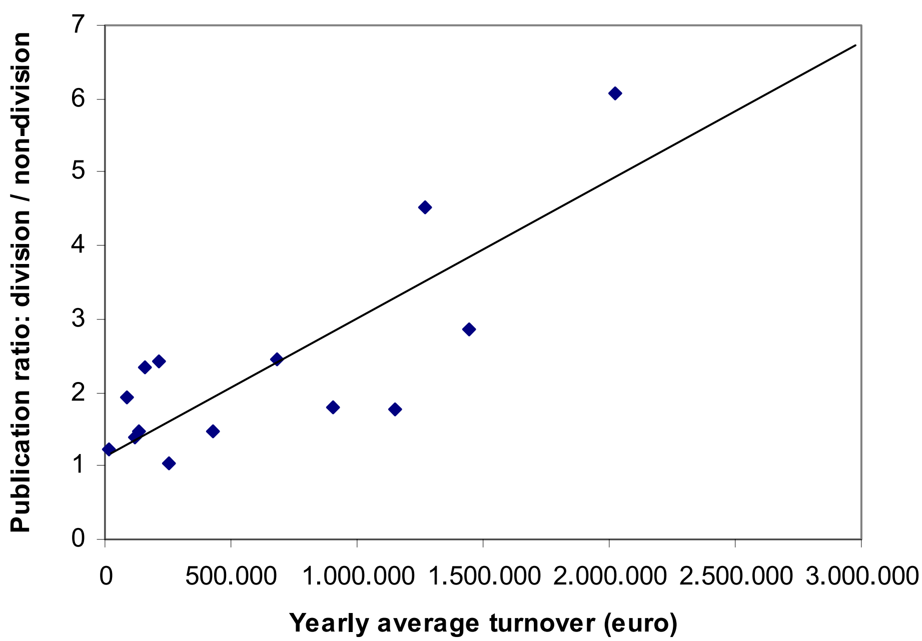
Semi-structured interviews were conducted to obtain an insight on factors that are considered conducive to combine performance in scientific as well as entrepreneurial activities. The open-endedness of the interview protocol left room for unattended factors to be touched upon, apart from three factors that were identified a priori. Explicit investigation of these factors was inspired by an analysis of the literature, as well as by exploratory conversations with professors at Katholieke Universiteit Leuven (Belgium). Each interview hence included an inquiry of the following themes: the presence of economies of scope, the role of financial resources and the role of the research unit in which the activities of professors are embedded.

If knowledge is considered an economic good, entrepreneurial professors could benefit from economies of scope (David, 1994; Foray, 2004), when involved simultaneously in different activities and various domains. *Economies of scope* occur if an asset (in this case: knowledge) 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 (Henderson and Cockburn, 1996). A broader access to relevant state-of-the-art, thanks to valorization efforts and interactions with industrial partners, might provide entrepreneurial professors with extra food for thought and might stimulate the formulation of additional research questions. As such, application and valorization activities may bring in new ideas that can serve the basic research agenda and reduce problems of problem choice (Zuckerman, 1978). Inversely, if fundamental research precedes commercialization activities and if knowledge is considered an 'asset', fundamental research can have direct value for application-oriented R&D (Lacetera, 2005). Hence, we are interested in exploring whether and how successful entrepreneurial professors benefit from economies of scope through their synchronic involvement in basic research and application-oriented valorization activities.

Besides positive effects rooted in the content of the research agenda, there is prior empirical evidence supporting the presence of *leverage effects from financial resources*. At the university level, Powers (2004) empirically showed a positive relation between federal R&D funding and technology licensing. This suggests a positive effect of basic research funding spilling over to the application side. In the opposite direction, financial resources gained from contract research with industry could lever basic research. In their questionnaire study among Norwegian professors, Gulbrandsen and Smeby (2005) found industry funding to be strongly correlated with high publication productivity. A similar effect was found by Van Looy et al. (2004) and is depicted in Figure 1.

Figure 1 – Publication ratio in relation to division turnover

(adopted from van Looy et al., 2004)



The figure maps the publication 'advantage' of professors who are members of a contract research division, meaning that they are structurally involved in research contracts with industry. As figure 1 clarifies, their publication advantage over a control group of non-division colleagues is more outspoken for contract research divisions with higher turnover. So research activities might benefit from industry funding through extra resources being acquired. In the interviews, we therefore also explore whether and how resources that are obtained through entrepreneurial activities are used for developing scientific activities.

One likely mechanism through which the latter could be achieved, is the translation of financial resources into human resources, redefining the scale of the research group. Much empirical work has been done on the relation between scientific performance and research group size and composition (Carayol and Matt, 2004; Groot and Valderama, 2006; Turner and Mairesse, 2003). These studies have yielded diverse results. Less empirical evidence is available on how human resources – that is the size and composition of the research group in which the activities of professors are embedded – can benefit the combination of scientific and entrepreneurial activities. Gulbrandsen and Smeby (2005) found industrial funding to be associated with a more collaborative mode of doing research. Collaboration was observed not only with external partners, but also with colleagues within the department. Also, the presence of a research group allows for more possibilities in terms of task allocation and specialization (Carayol and Matt, 2004). In as far as basic research and industry-oriented activities involve different role attributes (as for example suggested by George et al, 2006), having different persons focus on the one or the other could be instrumental in avoiding role conflict. Finally, to the extent that increased industry-orientation in research coincides with a higher need for multidisciplinary approaches, a heterogeneous research group could be more favorable for combining scientific and entrepreneurial activities. Therefore, the role of the research group was included as an explicit theme in the interview protocol.

The next section describes the main findings from these semi-structured interviews with successful academic entrepreneurs. In a synopsis, the general picture of relevant dynamics behind their scientific and entrepreneurial success is highlighted [iv].

A synopsis of professor’s stories

Application as an inherent part of understanding

Respondents indicate a high degree of topic overlap between their basic research agenda and the objects of valorization. Such overlap seems intrinsic to their conduct of research. In stating that “understanding presupposes applying and applying presupposes understanding”, most respondents situate themselves within Pasteur’s quadrant (Stokes, 1997). Table 3 summarizes their views in three categories and gives exemplary quotes.

Table 3 – Respondents' view on topic overlap between basic and applied activities

	Inventors	Non-inventors(*)	Quote
(1) Applications as byproducts (or even joint products) of basic research	11	0	*"There is total overlap: everything we publish we try to patent. […] This is due to our philosophy: if something is really interesting in biotechnology and life science, then it is also interesting for practical applications."*
(2) Feedback loops between basic research and applications	8	4	*"Many new ideas come up in the process of patenting. There is really a lot of cross fertilization. For example some specific applied questions require going all the way back to the theoretical formula and rethinking or rewriting them. So I have to go back all the way down to mathematics… It's really cross fertilization."*
(3) Keep basic and applied research sufficiently separated	4	3	*"When a company comes in and starts paying a number of people from the lab, it changes the dynamics. I don't think the lab has the right dynamics to run such a project: it is not the open free spirit environment. […] When you mix industry collaboration with the solid lab activity, you get confused people in the lab. So it's best to keep them separated."*

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

Over half of the inventors did not acquiesce in the distinction between scientific and application-oriented activities. A few are extreme in considering publications and applications as 'joint products'[v]. The others are more moderate, referring to applications as 'byproducts'[v] of their primordial activity, which is basic research[vi]. Respondents in the next category appear more tolerant towards the basic-applied distinction. They describe topic overlap in terms of continuous mutual feedback loops between basic and application-oriented activities. Inventors, when asked for pinpointing topic overlaps between their patents and publications, affirmed that everything that is patented, is also published. Both are outputs of one and the same research project. Development of the basic research agenda receives the highest priority. It is the driver behind all outputs, with publications covering the whole spectrum and industry-applications representing a subset of all the knowledge created. A minor share of respondents still argued for a separation between basic and applied activities. Their arguments are various: the academic setting still imposes taboos on application-driven research, collaboration with industry is seen as merely a way of getting access to specific resources, and some difficulties to balance short term application and long term fundamental research were being experienced.

The obviousness with which most professors point at high levels of topic overlap creates the impression that the flow from knowledge creation to applications is a spontaneous one, muting allegations on tensions. Further exploration of respondents' narratives reveals clues for qualifying such spontaneity. Crucial prerequisites are open-mindedness and sensitivity for valorization opportunities.

> Professor 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 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 Engineering Sciences: '*I am not oriented towards patenting. I am oriented towards not losing an opportunity to patent.'*

It is clear that no tensions are experienced between an entrepreneurial orientation on the one hand and the creation and maintenance of the basic research agenda on the other hand. The opposite is even expressed: scientific activities benefit from an orientation towards applications[vii]. With regard to alleged secrecy issues in relation to patent activity, respondents indicate that patents and publications are developed in parallel, with difficulties rarely occurring.

As such, allegations on industry-orientation negatively influencing the academic research agenda do not find support in this study. Moving beyond the conduct of science and the maintenance of the academic research agenda, respondents nevertheless mentioned some constraints to be taken into account when working with industry.

> <u>Professor Engineering Sciences, when asked about possibly negative effects of secrecy norms in industry:</u> '*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.'*

Respondents often associate difficulties to inexperience. Experienced professors have learned how to prevent tensions or trade offs. A synthesis of their stories reveals three important principles:

- **Selectivity:** selecting industry partners and projects for cooperation only if they respect and accommodate to the practices of the scientific environment.
- **Contract clarity:** being very clear when formulating contracts with industry partners; especially in relation to publishing.
- **Foresight and anticipation:** knowing what may be valuable for (commercial) development later on; and not going public with concepts or results before patent activities have been initiated.

In summary, the majority of respondents pointed out that understanding implies application and vice versa. As a consequence of situating their activities within Pasteur's quadrant, no major tensions or trade-offs between scientific and entrepreneurial activities are encountered. In addition, selectivity, contract clarity and anticipation are seen as important principles to enable and facilitate the co-existence of both types of activities.

The role of financial and human capital

To investigate how, at an individual level, resource dynamics underlie the combination of scientific and entrepreneurial activities, we inquired whether successful entrepreneurial professors benefit from the financial and human resources pertaining to their scientific and entrepreneurial activities.

Let it first be noted that at EPFL – and more generally in Switzerland – professors enjoy a relatively comfortable position in terms of scientific funding and research infrastructure provided by the school. Within our sample, no labs were found that need to tie the knots together. Therefore the argument that academic entrepreneurship would be driven by filling financial gaps seems less relevant in the context studied. A lack of financial dependence also implies that the academic partner has a relatively strong negotiation position in setting clear contractual agreements with industry, which in the previous section was mentioned as important to handle the risk of unintended industry interference with the academic work.

Notwithstanding their comfortable level of internal funding, respondents indicate that substantial effort is devoted to assembling the research group's 'external' budget portfolio. It consists of a combination of the following funding sources:

1) FNS: Swiss government money for basic research that is provided through funds of the Swiss National Science Foundation. Basic research projects are funded mostly through the payment of salaries of researchers.

2) CTI: 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'. CTI 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. CTI pays for the researchers' salaries; industrial partners finance their own expenditures and in addition contribute financially to the research activities of the academic institution.

3) EC: European money for projects executed in one of their research programs, which can be basic or applied research. Usually the project involves a network of European partners. These can be academic partners, but often also imply industry partners.

4) Industry funds: acquired through the execution of research mandates or research contracts. Involvement of the technology transfer office implies that an overhead is being paid to the school.

The share of industry funds is generally low. This does not imply a lack of cooperation with industry, but contract research with industry partners is usually framed within a CTI or EU program. Whether direct or earned through EU or CTI funds, Table 4 shows that most respondents do not consider industry-money as a substitute for traditional forms of basic research funding. Essentially, professors' comfortable financial position implies that they are not confronted with critical gaps – in their research budget - to be filled. More specifically for patenting and licensing activities, our inquiry among inventors shows that academic patenting does not pay off financially on the short term. Academics, when engaging in technology development appear to be mainly driven by non-monetary motivations[viii].

Table 4 – Respondents' view on whether industry funding fills gaps in basic research funding

	Inventors	Non-inventors	Total(*)	Quote
Yes, they can be considered substitutes	3	3	6	*"Let's put it this way: I do applied research in order to pay for my fundamental research. In fact, it's prostitution."*
No , they are complements	18	2	20	*"Whenever possible, I use the flexible money that comes from industry to complement the salaries. With the money from FNRS, we can pay salaries and a little bit of travel? But we will not be able to buy for example a computer from that."*

(*) For six respondents, it was unclear.

The positive relation between industry funding and research performance could be explained by an important complementary function of industry-originated money, to which over one third of the respondents pointed. These respondents indicate that their research activities benefit from a budget portfolio whereby part of the funding implies industry involvement. Basic research funding provides freedom to do exploratory innovative research and to work on new ideas in a curiosity-driven way. In contrast to the academic freedom in terms of research content, stands fierce budget rigidity: besides the salaries covered, almost no extra expenses can be accounted for. Industry partners from their side usually provide the researchers with more freedom in budget allocation. This allows for the creation of flexible funding pools that can be used for things like traveling, paying temporary employees and so on. But projects including an industry partner are often stricter in terms of research content and project organization: research direction and objectives are set from the start, and predefined deliverables are due at agreed upon deadlines.

> Professor 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 Engineering Sciences: *'Money from applied projects can serve as a kind of cement, for holding together the fundamental bricks that represent basic research funding.'*

Respondents hence perceive benefits from a budget portfolio which balances basic funding and industry-originated money. Focusing on one source would either hamper budget flexibility, or else define the project organization and research content too strictly. A positive relation between scientific and entrepreneurial activities may therefore be – partly – explained by the observation that resources acquired through entrepreneurial activities can be allocated flexibly, in turn benefiting the basic research activities.

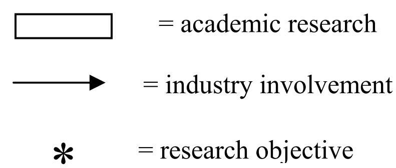
A preoccupation with budget composition rather than budget size may wrongfully create the impression that the latter does not matter. Importantly however, budget size primarily defines the scale of the research activities, even more so as a large part of the budget is immediately translated into human resources. As said previously, much empirical evidence is available on how group level factors influence research activities. Yet a specific point of interest in the interviews was whether there are specific group characteristics that enable the combination of research to valorization activities. Even when explicitly asked about this, professors' narratives still paint a pretty one-sided picture on how group characteristics influence research productivity, rather than on how they enable a combination of scientific and entrepreneurial activities. Groups consist mostly of PhD students, and - more or less permanent - senior researchers. Respondents point to the traditional inverse U-shaped relation between group size and productivity (Hackman, 1978); but they hereby consider research productivity and not entrepreneurial productivity. As for the role of group members in the entrepreneurial agenda, professors do not refer to the presence of PhD students as enabling. About one third of respondents even try to avoid having PhD students on industry-funded projects. They point out the risks implied both for the industry partner and the PhD student: deadlines may not be made and the project could eventually turn out to be an intellectually unrewarding dead-end. Most professors interviewed however deliberately involve PhD students in industry-oriented projects. But the purpose here is framed in terms of the benefits to the students: industry-involvement prepares them for a future industry career. The role of senior researchers and postdocs appears somewhat more conducive to entrepreneurial outputs. These group members are more easily mobilized in entrepreneurial activities, especially by professors who avoid having PhD students work on industry-related projects. In addition, but again affecting the research productivity rather than entrepreneurial outputs, senior researchers are said to ascertain some continuity in the basic research agenda: they constitute a more stable layer of critical mass compared to PhD's, who very often move out after finishing their projects[ix]. With this double function in the research group, senior researchers do appear to play a more pivotal role in combining and balancing basic research activities with more applied industry-oriented activities. Let it be noted finally that the mobility of PhD students can constitute an important channel for valorizing research and linking up with industry. For one thing, many of the startup activities are initialized because PhD students 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 create paths on which – in later stages – cooperative projects originate.

Taken together, additional resources that are acquired through entrepreneurial activities benefit the research activities undertaken. A balanced composition of the budget allows for the exploitation of complementarities between funding sources. Research group characteristics are seen as enabling for scientific activities, although entrepreneurial outputs can in some cases benefit from a complementary role of senior researchers.

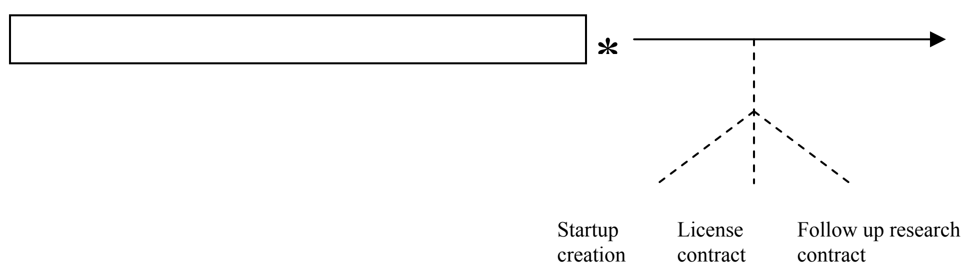
Cooperative scenarios moderating concerns and appropriate practices

Throughout respondents' narratives, many contextual factors were touched upon. Ample literature shows how national and institutional contexts can shape incentives for academic entrepreneurship (see for example Debackere, 2000; Goldfarb and Henrekson, 2003; Shane, 2004). Below this national and institutional layer, professors' stories in this study – confined to one institutional setting only – reveal a diversified picture of scenarios in which the relationships between university and industry are embedded. A synopsis of respondents' stories reveals three scenarios, depicted in Figure 2.

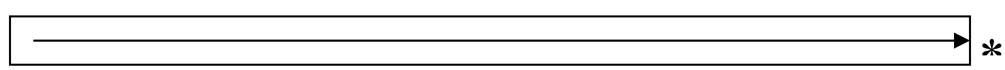
Figure 2 – Scenarios of university-industry linkage



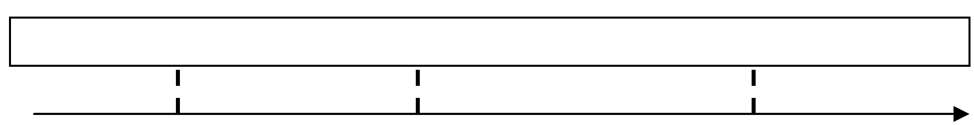
(2a) Research push - research result which is worth commercial development, brought out onto the market, industry partner only comes in after the research has been done.



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



(2c) Industry pull - research scouting by the industry partner – no fixed or predefined goal



The distinction between 'industry pull' and 'research push' scenarios is based on which partner primarily initiates the interaction. In the research push scenario (2a), academic research leads to some result that could be worth further development and valorization. Several avenues can be taken at this point: the academic partner can create a startup, or can take a patent and license it to industrial partners. The research result can also be a starting point for a follow-up project with an interested industry partner, illustrating how one valorization trajectory may be a sequence of different scenarios. The 'industry pull' scenarios all imply a first 'move' from industry but can be further distinguished by whether or not the initiated cooperation is directed towards a predefined goal. Scenario 2b represents a traditional research contract. The academic partner is paid for working on a problem or question that is advanced by the industry partner. Mostly, a specific output is to be delivered at some point in time upon which the partners have agreed. In scenario 2c, the academic researcher pursues his research agenda and some industrial partners become involved by providing additional funds: in turn these partners are allowed to 'scout' the research being done. The industry partners here are mostly large firms that can afford sponsoring research at several research institutions. No predefined objective is put forward by the industry partner.

While these different scenarios are not meant to provide an exhaustive mapping of collaboration modes, they do shed further light on the conditions that influence the reconciliation of scientific and entrepreneurial activities[x]. First, the timing and directions of feedback loops between scientific and valorization outputs – and consequent topic overlaps – should be considered in light of the scenario in which the university-industry interaction is embedded. For example in scenario 2b, the industry partner is most closely involved in the academic research process. Academic research in this scenario could be more vulnerable for industry influence than in scenario 2c, where the industry partner plays a much less active role. In scenario 2a, topic overlap is likely to be highest: the ‘byproduct’ conceptualization is most salient in this scenario.

Second, the relevance of ways for dealing with possible tensions (cf. supra) differs according to the interaction mode. ‘Selectivity’, in an industry pull scenario, essentially means accepting or rejecting projects. This decision influences research under scenario 2b more strongly than under scenario 2c. In the former, a subdivision of the academic research is actively ‘directed’ by the industry partner. In the latter, the industry partner plays a more detached role of supporting observer. In the research push scenario (2a), selectivity really means choosing a partner to transfer scientific findings to in later stages of development. The relevance of selectivity as a way to avoid difficulties depends on the avenue chosen. If the startup avenue is chosen, the industry partner is created rather than chosen. In some cases where the licensing avenue is chosen, selectivity is less of a concern because further activities are being transferred. However, to the extent that future cooperation is needed with the licensee for further development of the invention (see Jensen and Thursby, 2001), selectivity again becomes relevant as the avenue chosen then leads back to scenario 2b. Opportunities for success in the research push scenario are most importantly defined by the ability to foresee valorization potential. Foresight is even a necessary condition for scenario 2a to occur. In the two other scenarios, foresight of the industry partner can to some extent substitute for a lack of foresight at the academic side. The relevance of contract clarity, finally, is high in all three scenarios. The type of contracts is nevertheless contingent on the cooperation mode. A clause guaranteeing the publication possibility for the academic partner appears most important in scenario 2b. Related to this – and mostly important in scenario 2c – is an agreement that no part of the research being conducted can be made exclusive for use of the scouting industry partner. Scenario 2a often revolves around some licensing contract; these are mostly relatively standardized. Many respondents at this point indicate welcome support of the technology transfer office in defining and following up contractual agreements. Relating some of these contentions back to what was said in the interviews, Table 5 shows the frequency of associations between ways to deal with tensions and the specific scenarios[xi].

Table 5 – Frequencies of association between scenarios of university-industry linkage and mechanisms to avoid difficulties

	Scenario 2a (research push)	***Scenario 2b*** (industry pull – predefined objective)	***Scenario 2c*** (industry pull – scouting without objective)
Selectivity	5	8	3
Contract Clarity	1	3	1
Foresight	10	/	/

The research push scenario comes out as most prominent. This reflects the frequently expressed paradigm in which developments are byproducts of curiosity-driven research. Scenario 2b is also mentioned frequently, whereas scenario 2c is somewhat less cited. Taken together, 'selectivity' is mostly touched upon as a way to deal with difficulties that may arise from industry-involvement. 'Foresight' is also mentioned frequently but exclusively in association to the research push scenario.

'Selectivity' seems most relevant in industry pull scenarios with a predefined goal, 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 2b. An exploration like this shows how the exploitation of opportunities, discussed in the previous sections, is qualified by the specific setting in which the university-industry interaction takes place.

Conclusions

An in-depth exploration of academic entrepreneurs at EPFL, a renowned Swiss engineering school, offers insights into the mechanisms behind successfully combining scientific and entrepreneurial activities within academia.

Reassuringly, and in line with what is shown in most quantitative studies, this qualitative investigation reveals no fading of the traditional missions among entrepreneurial academics. Interviewees expressed a deeply-rooted sense of research as their main mission. The adoption of an entrepreneurial mission appears to even highlight the traditional mission, possibly because the danger of neglecting it becomes more pertinent.

Entrepreneurial professors indeed experience benefits from engaging in basic scientific activities on the one hand and industry-oriented applications on the other hand. A conceptualization in terms of 'knowledge spillovers between multiple activities' seems not appropriate as the paradigm by which our respondents conduct science essentially unites the activities of creating knowledge and valorizing it. A curiosity-driven basic research agenda is the common nominator out of which publications and entrepreneurial 'byproducts' originate. Experienced researchers have adopted several principles to deal with potential conflicts in practice: selectivity, contract clarity and finally foresight and anticipation. The acquisition of financial resources provides complementary benefits. Industry funds play an important complementary role, as they imply more flexibility in terms of allocation than traditional government funding for basic research. A successful combination of scientific and entrepreneurial activities appears to be facilitated by a balanced budget portfolio, which allows to achieve both budget and topic flexibility. The composition of the research group is seen as instrumental for improving scientific productivity rather than to contribute directly to a successful combination of research and entrepreneurial activities. Nevertheless, the role of senior researchers can be pivotal in scientific as well as entrepreneurial engagement. Finally, our respondents highlighted the importance of the specific scenario in which the university-industry interaction is being embedded. Three scenarios have been described, each implying particularities on the occurrence of potential tensions and the relevance of different coping strategies. Consideration of the different implications that each scenario entail, seems highly appropriate when further analyzing academic entrepreneurialism.

Overall, entrepreneurial professors, having adopted a proactive stance towards valorization, do enact several dynamics that allow them to become more effective in different activities. It seems that the exploitation of opportunities to successfully combine scientific and entrepreneurial activities not only presupposes a sufficient degree of strategic autonomy (Bailyn, 1984); the degree of autonomy itself is actually being enhanced by simultaneous involvement in different activities. Professors' autonomy in setting the research direction provides them with the opportunity of exploiting knowledge spillovers between understanding and application. At the same time, acquiring additional resources from industry creates additional degrees of freedom for effectively managing the portfolio of research activities. Strategic autonomy thereby also allows professors to engage in certain scenarios of industry-interaction and to avoid others, facilitating the alignment with an industrial environment. When such increased levels of strategic autonomy are framed within a triple strategic mission – covering research, education and valorization – the harvesting of opportunities, resulting in better performance, is likely to occur.

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i 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 activities and who at the same time remain among the top in terms of research output.

ii Web of Science publications with EPFL affiliation are counted; for the years 2000-2004. Category breakpoints represent the 33th and 66th percentiles.

iii In the selection of interview cases, a distinction was made between inventors and non-inventors. Interviews with 'non-inventors' nevertheless revealed that all but two of them were involved in some kind of industry-oriented activities; such as contract research with industry or startup involvement. Academic entrepreneurialism clearly goes beyond patenting and it proves difficult to find non-entrepreneurial professors, especially in the faculties considered here.

iv A detailed discourse on individual narratives is beyond the scope of this contribution, which by no means implies that we would consider the rich diversity of individual stories as irrelevant.

v 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 (for example patents), by using 'perceived value to the academic professor' instead of 'sales value'.

vi The views expressed by the respondents at this point support the suggestion of Breschi et al. (2005), who observed short run positive effects of publishing on patenting. These authors explained this by suggesting that patents are often byproduct of fertile research projects.

vii 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.

viii Indeed, also when asked about the main drivers of their involvement in entrepreneurial activities, professors mostly touched upon non-monetary factors. 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.

ix The observation on the complementary roles of permanent and non-permanent researchers is in line with what found in their analysis of the research productivity of French laboratories.

x For a well-documented similar exercise in the plant breeding sector: see Joly and Mangematin (1996)

xi 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.