



Scientific yield from collaboration with industry: The relevance of researchers' strategic approaches

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ABSTRACT

While recent research indicates that combining scientific and entrepreneurial activities at the level of academic scientists is feasible, the literature has remained muted on the dynamics behind such successful combinations. Indeed, little is known about how researchers avoid conflicts of commitment and conflicts of interest as well as the so-called 'skewing' of research agendas. This study, in seeking to address this gap in the literature, analyses the relevance of academics' strategic approaches to collaborative projects with industry. Based on survey data collected from engineering professors at two European universities (Politecnico di Milano, Italy: $n = 117$; and KU Leuven, Belgium: $n = 70$), we analyze whether the scientific yield from collaborative projects with industry depends on the degree of proactiveness, selectiveness and novelty of research topics. We observe that the scientific leverage of collaborating with industrial partners is higher when academics pursue a more proactive strategy and are selective. At the same time, our findings reveal that this impact is indirect: selectiveness and pro-activeness influence the amount of financial resources obtained from industrial partners, while the scientific yield itself is contingent on these resources.

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1. Introduction

The role of knowledge and technology transfer processes between public research centers and firms has been widely acknowledged and studied (Etzkowitz et al., 1998; Leydesdorff and Etzkowitz, 1998 for a comprehensive overview, see Rothaermel et al., 2007; Perkmann et al., 2013), leading to a diverse literature.

Research efforts have focused on the role and productivity of technology transfer offices, the role of intellectual property rights, the performance of universities in terms of outcomes (contract research, patent activity, spin-off creation) as well as environmental factors that might hamper or stimulate the entrepreneurial orientation of universities and researchers (e.g., Bozeman, 2000; Baruffaldi and Landoni, 2012; Perkmann et al., 2013).

The role of individual academics in their interaction with firms has received somewhat less attention (for notable exceptions (see

Jensen et al., 2003; Gulbrandsen and Smeby, 2005; D'Este and Patel, 2007). While institutional framework conditions do affect the behavior of academics in terms of engagement in knowledge transfer activities, academics in the majority of European universities still experience considerable degrees of freedom in defining their research agendas, including the choice of potential partners and funding resources for these research activities. Individual-level studies are also highly relevant because firms often approach researchers directly to obtain advice or to initiate specific research projects.

At the level of individual scientists, concerns have been raised about shifts in the academic research agenda toward industry needs, sometimes referred to as the 'skewing problem'. Moreover, the conflicting nature of the normative principles that guide academia and business (e.g., in terms of secrecy and dissemination of results) has, in addition, been advanced as an area of concern, leading to alleged conflicts of interest and conflicts of commitment (e.g., Dasgupta and David, 1987; Florida and Cohen, 1999; Noble, 1977). Empirical examinations show that a combination of scientific and entrepreneurial activities seems feasible in academia and may even yield positive effects. This has been confirmed in various fields and countries. For instance, in Belgium, it was shown that

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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, and there was no evidence of a trend toward a greater number of applied publications at the expense of basic research. Similar results were advanced by Gulbrandsen and Smeby (2005) in a survey of Norwegian professors. Breschi et al. (2005) observed no major trade-off between patenting and publishing, nor did they find evidence of a skewing effect among Italian inventors. Azoulay et al. (2007, 2009) and Meyer (2006) arrived at similar conclusions when studying US life scientists and UK, Belgian and German researchers in the field of nanotechnology. Czarnitzki et al. (2007) studied the publication and patent activity of German researchers. Stephan et al. (2007) looked at a cross-section of over 10,000 US doctorate recipients. Fabrizio and Di Minin (2008) performed a survey and quantitative analysis of US researchers in science and engineering disciplines. All of the above mentioned studies raised doubts about the alleged concerns by pointing to positive relations between scientific and entrepreneurial – mostly patenting – activities.

While the feasibility of combining scientific and entrepreneurial activities appears to be sufficiently supported, the empirical literature on the dynamics behind such successful combinations remains scarce. Little is known about how researchers avoid problems related to conflicts of commitment, conflicts of interest and the skewing of research agendas since aggregated results conceal variation in individual approaches and action strategies, whether successful or unsuccessful. Indeed, a study by Van Looy et al. (2006) showed that a successful alignment is by no means universal among the academics under study. Although, a positive relation between scientific and entrepreneurial activities was observed overall, clear cases of trade-offs were identified on the level of individual researchers. Starting from this latter observation, Callaert et al. (2008) engaged in a qualitative exploration of mechanisms enacted by academics, both in Belgium and Switzerland. They identified several action strategies that were used by entrepreneurial professors to manage their activity portfolios. Selectivity in projects and partners, a proactive approach toward collaboration, and securing topic relatedness between the research and entrepreneurial agendas figured prominently. At the same time, a more systematic – quantitative – analysis of the effect of such mechanisms remains lacking. Our study aims to fill this gap with an analysis of whether certain strategic approaches to collaboration with industry are instrumental in obtaining more scientific yield from collaborative industry–academia projects.

The remainder of the paper is structured as follows: in the following paragraph, we outline the hypotheses derived from the most pertinent literature; then, we introduce the data-gathering strategy adopted for the analyses and the relevant variables, constructs and indicators. A subsequent section covers our main findings, and we conclude by discussing the implications as well as the limitations of our work.

2. Research questions and hypotheses

As previously noted, the feasibility of combining scientific and entrepreneurial activities is adequately supported in different fields, industries, countries and activities (e.g., Van Looy et al., 2004; Stephan et al., 2007). However, some areas of concern remain, relating primarily to the impact of industry-related activities on scientific activities: alleged skewing of research agendas, as well as conflicts of interest and conflicts of commitment (e.g., Noble, 1977; Dasgupta and David, 1987; Florida and Cohen, 1999). Little empirical literature is available on how entrepreneurial academics avoid these issues, how they succeed in combining scientific and entrepreneurial activities, or even how they obtain

leveraging effects between the two activities. The answer to such questions cannot be gathered from aggregated results that hide variation in individual approaches and action strategies, whether successful or unsuccessful. Indeed, Van Looy et al. (2006), in their study of publication performance among academic inventors at KU Leuven (Belgium), showed that the positive relation between patenting and publishing is not a general phenomenon among academics. Although this positive relation was apparent in the overall sample, clear cases of trade-offs were identified on the level of individual researchers. Also, on the level of individual analysis, Callaert et al. (2008) engaged in a qualitative exploration of mechanisms enacted by entrepreneurial academics in Belgium (KU Leuven) and Switzerland (Ecole Polytechnique Fédérale de Lausanne). Among other findings, their study demonstrated that entrepreneurial researchers adopt several principles to deal with potential conflicts. More specifically, they are selective in their choice of project partners and topics, ensuring a sufficient degree of alignment with their ongoing academic research activities. These interviews also highlighted the relevance of collaborative scenarios. In ‘research push’ scenarios (as opposed to ‘industry pull’ scenarios), the researcher initiates the collaboration (as opposed to the industrial partner), allowing him/herself greater freedom in selecting topics and partners for better alignment with his ongoing activities. Finally, entrepreneurial academics indicated that the acquisition of financial resources from entrepreneurial activities provided complementary benefits that could be invested in their ongoing research activities.

The above mentioned observations are based mainly on qualitative evidence. Further validation of the suggested relations between individual-level strategic collaborative approaches and scientific yield would benefit from a systematic analysis based on quantitative data. This is the objective of this study, which relies on an analysis of survey data to establish whether researchers’ individual strategic approaches to collaboration with industrial partners affect the scientific yield of these collaborative projects, i.e., the research output resulting directly from these collaborations.

In particular, we relied on the highlighted literature to identify three strategic approaches used by entrepreneurial professors: (i) securing the appropriate degree of topic alignment between the academic research agenda and collaborative projects; (ii) a proactive approach to collaboration; and (iii) selectiveness in projects and partners. In what follows, hypotheses are formulated for each of the three approaches considered.

First, since many concerns are related to the potential impact of university–industry collaboration on the academic research agenda, we consider topic alignment between collaborative projects and the academic research agenda. The impact of collaboration on the setting of research agendas was indicated by Joly and Mangematin (1996). They stated that, for researchers who grasp the opportunity offered by relations with industry, there is co-determination regarding their scientific themes. One may expect a higher scientific yield in the case of greater topic alignment. In evolutionary thinking, knowledge production is often described as a cumulative, interactive and path-dependent process (Dosi, 1982; Nelson and Winter, 1982) whereby agents tend to draw on knowledge acquired in the past. As Cohen and Levinthal (1990) argued, agents are more likely to understand, absorb and implement external knowledge when it is close to their own knowledge base. Indeed, the arguments are similar to those that posit the presence of absorptive capacities in firms. Much in the same way that firms are better able to acquire and use external knowledge from areas in which they have some prior experience or related knowledge (e.g., Cohen and Levinthal, 1990; Dussauge et al., 2000; Leten et al., 2007), we can expect researchers to perform better if they can leverage their previous or ongoing work. And while one could argue that researchers’ productivity can also benefit from widening the scope

of their research agenda – by becoming engaged in diverse topics – it is clear that benefits in terms of knowledge creation and hence publications are more uncertain and will imply longer timeframes. Therefore, we expect collaborative projects that exploit previous or ongoing research to yield greater scientific results due to their relationship with existing knowledge, databases and experience. Thus, we formulate our hypothesis as follows:

H1. The scientific yield from collaborative projects will be higher for professors who engage in industry collaboration on topics close to their current focus/research agenda.

Second, we argue that proactiveness (i.e., a ‘research push’ rather than a ‘market pull’ scenario, cf. supra) benefits performance. Proactiveness, in general, has been shown to relate positively to professional performance on both the organizational level and the individual level (see e.g., Belschak et al., 2010; Seibert et al., 1999; Baer and Frese, 2003). Furthermore, the importance of technology proactivity has been argued and empirically tested (e.g., Fiol and Lyles, 1985; García-Morales et al., 2007). The effect of proactiveness in the specific context of academic entrepreneurship was supported in the above mentioned qualitative study by Callaert et al. (2008). Entrepreneurial professors mentioned pro-activeness in collaborating with industry as instrumental in avoiding conflicts of commitment between academic and collaborative activities. The reasoning is similar to the arguments advanced by Joly and Mangematin (1996) when analyzing the collaborative strategies of French research laboratories. The authors discuss the dependence versus independence continuum in research laboratories. ‘Dependence’ is associated with what we refer to as ‘reactivity’. According to the authors, dependent laboratories receive diverse orders through a number of interpersonal and professional networks. Contracts will often be short, involving small amounts, and the researchers will have to make a considerable effort to find, negotiate and realize them. In order to handle diverse offers, laboratories are required to mobilize and allocate resources in such a way that they are prevented from focusing on a specific theme. Hence, efforts will be of a dispersed and ad hoc nature, hampering scientific publications which require focus and commitment over longer time periods. By advancing this argument, we do not deny that collaboration with (especially research-intensive) firms could provide opportunities for broadening the scope of the research, by introducing novel insights, which could in turn benefit researcher productivity. However, following the arguments that dependence (reactivity) is more likely to conflict with the present scientific focus, while the opposite holds when a proactive stance is being adopted, we propose the following hypothesis:

H2. The scientific yield from collaborative projects is higher for professors who adopt a proactive approach.

Finally, selectiveness can also be expected to play a significant role. Notwithstanding the limited empirical evidence and the existence of theories that favor breadth and diversification in innovation processes, the literature also suggests there may be disadvantages in undertaking a wide range of innovation attempts or in spreading efforts over a greater number of innovation services. These disadvantages include reduced managerial attention to individual projects, diminished strategic focus, heightened organizational complexity, and lowered incentives (Sull, 2003; Tidd and Hull, 2006; Laursen and Salter, 2006; Klingebiel, 2010; Boudreau et al., 2011).

In line with these considerations, more selective professors can be expected to focus their efforts on what they judge to be the more promising projects, i.e., projects that are deemed more likely to yield gains. In the above mentioned study by Callaert et al. (2008), entrepreneurial professors mentioned selectiveness as a way of assuring alignment between their industry-related activ-

ities and their academic work. This alignment is broader than the topic alignment referred to in Hypothesis 1 because selectiveness covers other objectives as well. As discussed in Section 3, selectiveness is also concerned with time constraints and the choice of industrial partners who can adapt to the academic environment in terms of financial, dissemination, and intellectual property agreements whereby the latter could be facilitated by prior collaboration experiences with specific industrial partners. By focusing efforts on partners and projects that facilitate the emergence of mutually beneficial agreements, scientists can avoid conflicts of interest and create better environments and opportunities for their research. We, therefore, propose the following hypothesis:

H3. The scientific yield from collaborative projects is higher for professors who opt for a higher level of ‘selectiveness’ in their choice of projects and partners.

It is acknowledged that, besides the strategies deployed, other factors determine the scientific yield of collaborative projects. These will be included as control variables. In particular, as highlighted in the literature, the important role of human and financial resources will be considered. The following section describes the data (measurement of the focal and control variables) and the empirical approach in greater detail.

3. Data and methodology

The analyses are based on a survey conducted among engineering professors at two universities: Politecnico di Milano in Italy and KU Leuven in Belgium. Although KU Leuven has a longer tradition in technology transfer, both universities have an explicit entrepreneurial orientation and are characterized by similar regulations and attitudes to managing knowledge and technology transfer. Witness to this established practice is the presence of a technology transfer office in both universities, where patenting activities and research contracts and networks with industrial partners are managed professionally. In addition, both universities play active roles in the development of spin-off companies and facilitate the development of innovative entrepreneurship through the creation of regional business incubators.

In both universities, the targeted sample of researchers was restricted to autonomous professors, being those who can establish research contracts and who lead research teams (of PhDs, post-doc researchers and assistant professors). The focus is on professors in engineering, a field in which collaborative research between university and industry is common and directly relevant to knowledge-intensive innovation. Eight engineering sub-fields are distinguished and controlled for in the analyses. The largest is Electric Engineering (approximately 30% of respondents). Chemical Engineering and Mechanical Engineering both have approximately 15% of respondents. Civil and Environmental Engineering, Biology & Bioengineering, and Energy each have 10% of respondents. And some minor sub-fields are included, namely Aerospace, and Physics, Astronomy and Computer Science, each providing less than 5% of respondents. There are institutional differences in the constellation of sub-fields within the two universities. For instance, the largest share of respondents at KU Leuven (25%) is in Biology and Bioengineering whereas, in Politecnico di Milano, most respondents (35%) are to be found in Electrical Engineering.

Data were collected primarily through a questionnaire, sent to all engineering professors in the two universities. After several follow-up rounds, response rates were approximately 30% for Politecnico di Milano (116 professors) and 34% for KU Leuven (70 professors). Each professor was asked to provide information regarding his/her collaborative research and projects with industrial partners. 20% of respondents indicated they had not been involved in any collaborative projects with industry over

the preceding five years. They were eliminated from the analyses, which focus on the effects of collaborative strategies rather than on the effects of collaboration per se. Indeed, the variables of our main interest relate to the researcher's strategic approach to collaborative projects with firms. Three aspects of this strategic approach are considered:

- 'Novelty' (the reverse of 'topic relatedness') refers to the extent to which collaborative projects with industry imply the introduction of new research topics to the researcher's agenda.
- 'Proactiveness' is measured as the proportion of projects initiated by the researcher, as opposed to projects initiated by the partnering firm.
- 'Selectiveness' is measured as the frequency with which the researcher has, in the past, refused proposals for research collaboration with industrial partners.

All three strategy-related variables are self-reported, i.e., based on the researchers' survey responses. The same holds for several control variables that are introduced into the analyses, characterizing the researcher's field of activity and the size of his/her research team. Since the size of the research team indicates human resources, the researchers were also asked to indicate the financial resources obtained from collaborative projects with industrial partners by providing details of the acquired budget (as these data are unavailable from secondary sources). To measure the 'scientific yield' from collaborative projects, which acts as the dependent variable, researchers were asked to make an estimation of the number of publications resulting from their collaborative projects with industry. The data relating to the researcher's overall scientific productivity and scientific impact (acting as control variables)¹ were extracted from the ISI Web of Science covering the period 1990–2008 (but excluding those years in which the researcher was not active as a researcher). Table 1 provides an overview of the variables and data sources used in the analyses.

4. Analyses and results

4.1. Descriptive statistics

Before analyzing the effect of collaborative strategies on scientific yield, some basic descriptive statistics of the main variables are presented (Table 2). The average professor in the surveyed sample is 54 years old and leads a team of approximately eight researchers. His/her overall scientific productivity, as measured by publication records in the Web of Science, is 2.5 articles on average per year, with an average impact of 5 citations received per publication (over a 5 year citation window). In terms of collaboration with firms, respondents have acquired a budget from collaboration of €768,910 on average, over the five-year time period (between 2003 and 2007) and comprising the budget acquired by all researchers in their team. This budget includes direct firm funding as well as financial support from a range of competitive university/industry projects such as EU framework programs and national programs financing collaborative research. Responding professors indicate that these collaborative projects with firms have resulted in 21 publications on average over the specified five-year period.

¹ Note that scientific productivity and impact could also be conceived as 'dependent' variables. This however, would require that for each publication one would be able to identify whether or not it resulted from collaboration with industry. As such we opted for distinguishing between overall scientific productivity (and impact) – measured by data extracted from the ISI Web of Science – as control variable, and scientific 'yield' – obtained from the questionnaire – as dependent variable.

In terms of strategic approaches to collaboration, the proportion of projects introducing novel topics to the research team (in their project portfolio) is evaluated. On average, 70% of the projects did not imply new topics; moreover, 90% of respondents indicate that less than half their collaborative projects involved new topics/themes for the research team. Hence, alignment with ongoing or previous research would appear to be corroborated as a relevant consideration by researchers undertaking collaborative projects with industrial partners. It should be noted that this alignment may also be introduced by the partnering firms, as they tend to collaborate with scientists who are experts in their field; thus, they are more likely to engage in a collaborative projects situated within that researchers' field of expertise. Stated otherwise, topic alignment will partly be due to an explicit strategy of the researcher and partly to the distribution of opportunities offered by the partnering firms.

Proactiveness is measured by the percentage of collaborative projects where the initiative for the project came from the researcher ('research push' scenario) rather than from the firm soliciting the researcher for collaboration ('market pull' scenario). Almost 25% of respondents report a 50–50 distribution between projects initiated by them (push) and projects solicited by the firm (pull). Another 25% reported a higher proportion of proactive scenarios in their collaborative portfolios. The remaining 50% of respondents reported more reactive projects. Consequently, pull scenarios (where firms initiate collaborative projects with university researchers) appear to occur more frequently than push scenarios.

Finally, 'selectiveness' is measured by the frequency with which respondents, in the past, turned down proposals for collaborative projects with industry. The results suggest that respondents are generally inclined to accept collaborative projects: almost 70% indicate that they have 'never' or 'hardly ever' refused a proposal for collaboration. Note that this observation may, in part, be due to a selection effect. Survey respondents are by definition professors who have collaborated with industry in the specified five-year period. Therefore, professors who would generally refuse collaborative projects will be severely underrepresented in the surveyed sample. At the same time, the frequency of refusals varies among respondents; almost 10% indicate that they sometimes or frequently refuse proposals for collaboration. Additional items in the survey further investigated the reasons for refusals, which are broader than the mere alignment between research agendas. Table 3 provides the reported reasons for refusal for all professors who confirm they have declined offers of collaboration. Although topic alignment is an important factor, it can be seen that time constraints and the absence of satisfactory budget arrangements are further reasons for selectiveness. Concerns about intellectual property rights and dissemination of research results appear much less relevant. Finally, researchers had the opportunity of specifying "other reasons" for not engaging in collaboration. 10% of respondents did indeed specify other reasons, the majority of which related to the content of the collaboration projects. Some suggested a lack of resources, too short term objectives and finally possible conflict of interest (resulting from previous engagements in collaborative research with other firms).

4.1.1. Hypothesis testing

A first look at the relations between the variables of interest is provided in Table 4, presenting the correlations between our variables of interest. It can be seen that the three strategy-related variables (novelty, proactiveness, selectiveness) are uncorrelated. This means that they can be modeled together without the introduction of multicollinearity issues. Moreover, the relation of individual researcher characteristics (age, team size) with scientific productivity shows the relevance of these characteristics as

Table 1
Summary of variables used.

	Description	Source	Period
University	KU Leuven (BE) or Politecnico di Milano (IT)	Sample	Time of survey
Age	Age in 2009	Survey	
Field	Sub-fields: - Aerospace - Bioengineering - Chemistry - Civil & Environmental Engineering - Electrical - Energy - Mechanical Engineering - Physics, Astronomy & Computer Science	Survey	Time of survey
Teamsize	Number of researchers (including self, PhD students, post-docs, researcher assistants, ...)	Survey	Yearly average of period 2003–2007
Scientific productivity	Number of published articles	ISI Web of Science	Yearly average of period 1990–2008
Scientific impact	Average number of forward citations received per published article (5 year citation window)	ISI Web of Science	Yearly average of period 1990–2008
Project publications (scientific yield)	Self-reported number of publications resulting from collaborative projects from the past five years	Survey	Time of survey
Collaborative strategy: proactiveness	% of research collaborations with firms that were proposed (initial idea/contact) by the respondent professor or his research team (versus proposed by the firm partner)	Survey	2003–2007
Collaborative strategy: novelty	% of collaborative projects that involve new topics (as opposed to topics from the ongoing or previous research agenda)	Survey	2003–2007
Collaborative strategy: selectiveness	Frequency of refusals of requests for collaborative projects with industry (on a scale from 1 = never to 5 = frequently)	Survey	Period preceding the survey
Budget from collaboration	Sum of the budget acquired from research projects directly funded by industrial partners and the budget from research projects with firms funded by competitive programs	Survey	2003–2007

Table 2
Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. deviation
Age	148	35	75	54.39	9.37
Team size	147	.00	42	8.38	7.81
Budget from collaboration	103	.00	4000	768.91	942.45
Publications yielded from collaborative projects	116	0	105	21.08	26.54
Overall scientific productivity	148	0	12	2.54	2.35
Average scientific impact	141	.20	27.48	5.63	4.36
Proactiveness (% of projects proposed/initiated/first contact by research team)	140	.00	100.00	39.70	30.42
Novelty (% of projects that implied new topics)	130	.00	100.00	29.42	24.82
Refusals (1–5 scale for frequency of refusals of collaboration offers in the past 5 years: 1 = never; 5 = frequently)	138	1	5	2.17	.879

control variables. Variables depicting resources (human resources measured by team size and financial resources measured by the collaboration budget) are correlated with each other, and are also correlated with scientific output (the researcher's overall scientific productivity, impact as well as the scientific yield from collaborative projects).

In the sections that follow, we analyze whether (deliberate) strategies or intentional behavior in relation to collaborative research with firms are important for the scientific yield from these collaborative projects. For the dependent variable, we use the (self-reported) 'number of publications resulting from collaborative projects from the past five years', as recorded in the survey. The independent variables are the three strategies: novelty (the proportion of collaborative projects that involve new topics,

as opposed to topics related to the researcher's current or past research agenda); proactiveness (the ratio of collaborative projects that were initiated by the researcher versus those that were initiated by the industrial partner); and selectiveness (frequency of refusal of collaborative projects with industry). In addition, several control variables are included. First, we control for the researcher's characteristics: his/her age and the discipline in which he/she is active. Second, we include variables related to available resources or to the scale of activities: the researcher's team size and the budget that has accrued from collaborative projects over the designated five-year period. Third, we control for the researcher's overall scientific capabilities (measured by his/her number of published articles over the course of his/her career and by the average impact of their publications). The correlations between the relevant

Table 3
Selectiveness: Reported reasons for refusing collaboration.

Reason for refusal	No		Yes		Total	
Lack of time	75	57.69%	55	42.31%	130	100%
Lack of topic alignment	57	43.85%	73	56.15%	130	100%
No satisfactory financial agreement	84	64.62%	46	35.38%	130	100%
No satisfactory agreement on dissemination	123	94.62%	7	5.38%	130	100%
No satisfactory agreement on IP	120	92.31%	10	7.69%	130	100%

Table 4
Correlations.

		Age	Team size	Proactiveness	Novelty	Selectiveness	Sci. prod.	Sci. yield	Sci. impact	Collab. budget
Age	Pearson correlation	1	.047	–.031	.100	.135	–.287**	–.003	–.292**	–.037
	Sig. (2-tailed)		.577	.720	.256	.115	.000	.973	.000	.712
	N	144	144	140	130	138	144	115	141	102
Team size	Pearson correlation	.047	1	.297**	–.079	.145	.355**	.447**	.193*	.487**
	Sig. (2-tailed)	.577		.000	.371	.091	.000	.000	.022	.000
	N	144	144	140	130	138	144	115	141	102
Proactiveness	Pearson correlation	–.031	.297**	1	.089	.054	–.022	.311**	.129	.369**
	Sig. (2-tailed)	.720	.000		.312	.531	.795	.001	.132	.000
	N	140	140	140	130	136	140	115	138	98
Novelty	Pearson correlation	.100	–.079	.089	1	–.063	–.099	–.139	–.002	–.119
	Sig. (2-tailed)	.256	.371	.312		.480	.264	.147	.986	.251
	N	130	130	130	130	127	130	110	129	95
Selectiveness	Pearson correlation	.135	.145	.054	–.063	1	.066	.128	–.013	.180
	Sig. (2-tailed)	.115	.091	.531	.480		.444	.178	.880	.079
	N	138	138	136	127	138	138	112	135	96
Sci. prod.	Pearson correlation	–.287**	.355**	–.022	–.099	.066	1	.147	.519**	.185
	Sig. (2-tailed)	.000	.000	.795	.264	.444		.118	.000	.062
	N	144	144	140	130	138	144	115	141	102
Sci. yield	Pearson correlation	–.003	.447**	.311**	–.139	.128	.147	1	.005	.470**
	Sig. (2-tailed)	.973	.000	.001	.147	.178	.118		.961	.000
	N	115	115	115	110	112	115	115	114	83
Sci. impact	Pearson correlation	–.292**	.193*	.129	–.002	–.013	.519**	.005	1	–.109
	Sig. (2-tailed)	.000	.022	.132	.986	.880	.000	.961		.281
	N	141	141	138	129	135	141	114	141	100
Collab. budget	Pearson correlation	–.037	.487**	.369**	–.119	.180	.185	.470**	–.109	1
	Sig. (2-tailed)	.712	.000	.000	.251	.079	.062	.000	.281	
	N	102	102	98	95	96	102	83	100	102

* $p < 0.05$.** $p < 0.001$.

variables as presented in Table 4 do not reveal any multicollinearity threats. The results of the ANCOVA analysis are shown in Table 5.

The results in Table 5 show no relation between the three strategies and scientific yield. Thus, the results of this first analysis do not support our research hypothesis on the importance of strategies. At the same time, the results show that the scientific yield is driven exclusively by the variable related to financial resources, i.e., by the budget acquired from collaborative projects. Even researchers' characteristics and their overall scientific capabilities (productivity and impact) appear unrelated to the scientific yield of their collaborative projects.

As resources appear to be crucial in determining the scientific yield, a second model analyses the relation between strategies and resources (the budgets acquired from collaborative projects), again controlling for the researcher's characteristics. Results are shown in Table 6.

In contrast to the previous model, the results in Table 6 reveal the relevance of strategic approaches in collaborative projects. More specifically, proactiveness and selectivity are positively related to the budget that is acquired from collaborative projects with industry. In addition, as expected, there is a positive relation between the researcher's overall scientific productivity and her collaborative budget. At the same time, no such relation was found between

Table 5
ANCOVA: determinants of the scientific yield of collaborative projects.

Tests of between-subjects effects						
Dependent variable: scientific yield from collaborative projects						
Source	Type III sum of squares	df	Mean square	F	Sig.	Param. estim. (B)
Corrected model	47.447 ^a	15	3.163	2.995	.001	
Intercept	.041	1	.041	.039	.844	–.011
Field	4.210	7	.601	.569	.778	
Sci. prod.	.091	1	.091	.086	.770	–.090
Sci. impact	.085	1	.085	.080	.778	–.072
Budget from collaboration	8.832	1	8.832	8.362	.005	.344**
Selectiveness	.928	1	.928	.878	.352	.154
Novelty	1.171	1	1.171	1.108	.297	–.006
Proactiveness	.108	1	.108	.102	.750	.002
Team size	3.219	1	3.219	3.048	.086	.044
Age	.145	1	.145	.138	.712	–.006
Error	65.485	62	1.056			
Total	571.454	78				
Corrected total	112.932	77				

^a R squared = .420 (adjusted R squared = .280).** $p < 0.001$.

Table 6
ANCOVA: determinants of the budget acquired from collaborative projects.

Tests of between-subjects effects						
Dependent variable: budget from collaboration						
Source	Type III sum of squares	df	Mean square	F	Sig.	Param. estim. (B)
Corrected model	107.383 ^a	14	7.670	5.934	.000	
Intercept	7.074	1	7.074	5.472	.022	3.887 [*]
Field	22.154	7	3.165	2.448	.026	
Sci. prod.	5.767	1	5.767	4.461	.038	.592 [*]
Sci. impact	3.300	1	3.300	2.553	.114	-.410
Selectiveness	7.667	1	7.667	5.931	.017	.375 [*]
Novelty	.333	1	.333	.257	.613	.003
Proactiveness	14.048	1	14.048	10.868	.001	.015 ^{**}
Team size	5.898	1	5.898	4.562	.036	.046 [*]
Age	4.533	1	4.533	3.506	.065	.031
Error	98.243	76	1.293			
Total	3417.941	91				
Corrected total	205.625	90				

^a R squared = .522 (adjusted R squared = .434).

^{*} $p < 0.05$.

^{**} $p < 0.001$.

scientific impact and collaborative budget, suggesting that attracting budgets benefits from publications (signaling expertise) rather than from the actual (average) impact of these publications.

Taken together, the results from the different models indicate that a researcher's strategies concerning collaboration with industry have no direct effect on his scientific yield from these projects. However, strategies have an important direct effect on the acquired budget. This budget is then translated into scientific yield. More specifically, the results suggest that researchers who are more proactive and more selective in their approach to collaboration with industry are able to obtain larger budgets from these collaborations. The size of the budget obtained from collaborative projects with industry turns out to be an important determinant of the scientific yield of these projects.

Hence, greater nuancing is required in the propositions advanced in Hypothesis 2 and 3: the publication harvest from

collaboration with industrial partners is indeed higher when academics pursue a more proactive strategy of collaboration with industry and when there is a higher selectiveness, but these effects are indirect and driven by a budget increase.

At the same time, the results do not support Hypothesis 1 regarding the impact of topic relatedness. We find no confirmation of the argument that topic alignment – with previous or ongoing research (as opposed to projects implying new topics) – leads to greater scientific yield from collaborative projects. It could be that a certain degree of novelty is needed to stay at the frontier and to be able to publish novel results; whereas, at the same time, there may be a threshold beyond which too much novelty hampers capitalizing on existing knowledge and previous work (disturbing the potential for cumulative knowledge development). However, the consequential quadratic effect of novelty is not observed in our results, which may stem from the fact that the equilibrium may be

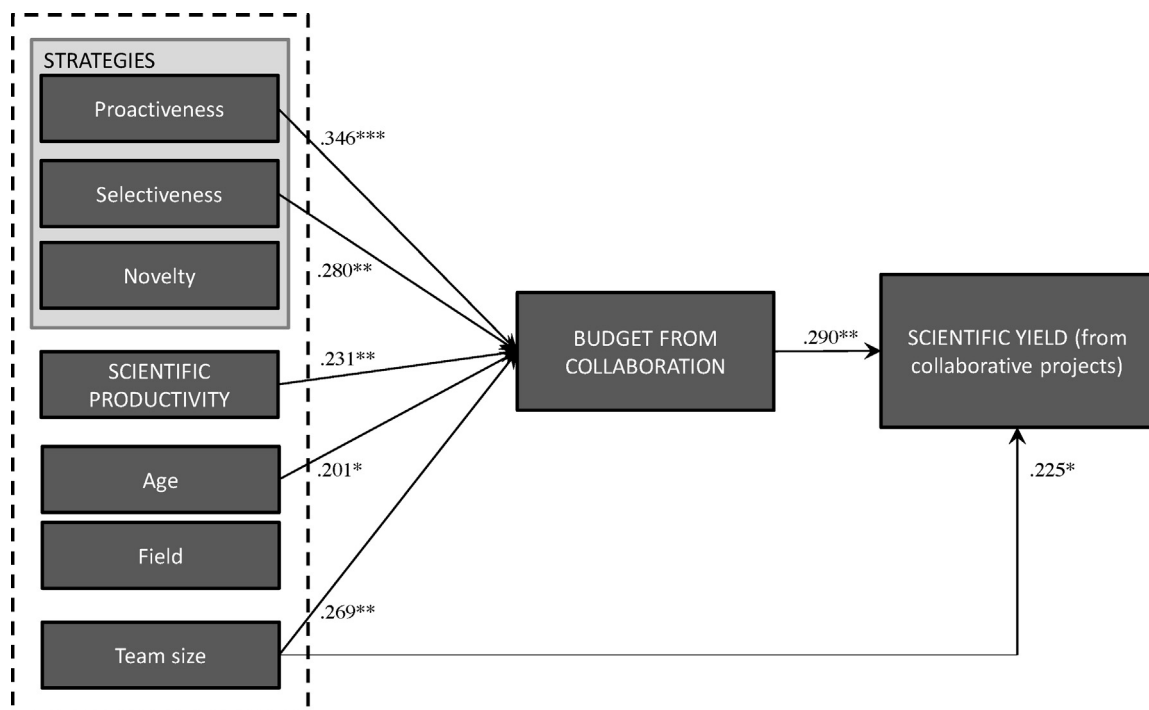


Fig. 1. Determinants of scientific yield from collaborative projects (partial correlation coefficients).

difficult to measure as it is most likely field and topic specific. Moreover, the effect of the degree of novelty may well depend on the degree of diversity already present in the existing research agenda. Since the latter variable is regrettably absent from our database, we acknowledge the need for further research adopting a more precise delineation of topic alignment.

Besides the two strategies (pro-activeness and selectivity), overall scientific productivity is influencing the size of the obtained budget, thereby indirectly leveraging the scientific yield of collaborative projects. Likewise, age and team size play a positive role. These results are synthesized in the scheme presented in Fig. 1.

5. Conclusions

While the feasibility of combining scientific and more entrepreneurial activities has been widely supported, the literature has remained rather silent on the dynamics behind such successful combinations. This contribution aimed to fill that void by analyzing to what extent different strategies for collaboration affect the resulting scientific yield. Our findings revealed that a more proactive approach and greater selectivity pay off in terms of scientific yield from these projects. However, the impact is not direct: these effects are moderated by the financial resources obtained from the collaborative projects. This is consistent with the evidence suggesting that larger research groups and research groups with superior equipment and infrastructures are more able to develop higher quality research. Furthermore, financial stability and opportunities allow leading scientists to be more selective and to hire and maintain the best scientists.

The findings support the relevance of investigating specific action strategies for securing successful combinations of industry-oriented and scientific activities. A number of knowledge and technology transfer policies have been designed to encourage firms to collaborate with research centers and universities, e.g., through financial support and competitive funds linked to the presence of research partners. Our findings show the potential relevance of aiming such policies at professors, encouraging them to be more proactive toward firms. If, additionally, professors enact sufficient selectivity to validate those research endeavors in terms of their relevance, such policies could foster knowledge transfer to firms and, at the same time, yield positive results with respect to scientific performance. Also selectivity seems to play a positive role, albeit the observed, positive, relationship might be partially resulting from the presence of a “Matthew” effect (Merton, 1968, 1988) whereby the most visible and best connected scientists are more likely to be approached by firms, hence they are more likely to turn down offers for collaboration (due to resource constraints). Even then however, selectivity remains a deliberate strategy, as researchers face the question which projects to engage in and which to turn down.

Some limitations in this study suggest directions for further research. First of all, it should be noted that the unit of analysis in this study consists of researchers’ collaborative project portfolios over a five-year period. Complementing these analysis by considering strategies for collaboration and scientific yield on the level of projects seems highly relevant as certain project characteristics – e.g., length, type and history of partnership, financial scale and source of financing – might influence the scientific output from projects. Second, it will be useful to extend the survey to other universities and countries in order to further examine the potential influence of institutional differences (between countries, universities and disciplines). Moreover, broadening the scope in terms of disciplines by going beyond engineering could reveal field differences regarding the role of industrial partners and the relevance of strategies. Biomedical sciences may be a case in point, as the profile of pharmaceutical firms and the science intensive

nature of the implied R&D activities may provide more opportunities for mutually beneficial collaboration with scientific partners. Third, engaging in a longitudinal analysis (panel data analysis) to examine the robustness of the results over time and the impact of a change in strategies could prove valuable. Furthermore, the majority of our respondents collaborate with industrial partners. It would be interesting to extend this analysis to include the experiences and opinions of professors who discount collaboration with firms. Additional analysis could also include technological activities (patents), their relation to scientific performance and how they are moderated by the strategies explored. Finally, future research could focus more precisely on topic alignment and disentangle further the nature and impact on scientific performance. We do hope that the research reported in this article inspires such future research endeavors.

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