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To cite this version:

Quentin Plantec, Benjamin Cabanes, Pascal Le Masson, Benoit Weil. MARKET-PULL OR RESEARCH PUSH? EFFECTS OF RESEARCH ORIENTATIONS ON UNIVERSITY-INDUSTRY COLLABORATIVE PH.D. PROJECTS' PERFORMANCES. Academy of Management Conference 2021, Jul 2021, Philadelphia, United States. halshs-03190142

HAL Id: halshs-03190142
https://shs.hal.science/halshs-03190142

Submitted on 6 Apr 2021

MARKET-PULL OR RESEARCH PUSH? EFFECTS OF RESEARCH ORIENTATIONS ON UNIVERSITY-INDUSTRY COLLABORATIVE PH.D. PROJECTS' PERFORMANCES

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ABSTRACT: There is abundant literature on the consequences of academic engagement with the industry, on overall scientists' commercialization and scientific performances. Nevertheless, the literature remains silent on how those performances are contingent on the research orientation's choice at the project level. This paper aims to fill this gap by exploring different research orientations in the context of university-industry collaborative Ph.D., a topic of interest as private companies are becoming more involved in Ph.D. training. To do so, we relied on a unique dataset comprising of 635 Collaborative Ph.D. projects through the CIFRE program in France. We classified the projects' ex-ante research directions: market-pull-oriented (MPO), research-push-oriented (RPO), and simultaneous-discovery-invention-oriented (SDI), and we observed their ex-post performances. First, as expected, an orientation towards industry needs conduct to higher commercialization performances. However, counter-intuitively, those projects are also prone to have similar scientific performances than those oriented towards scientific discoveries. Second, while SDI projects were considered over-performing other research orientations, they led to more significant scientific performances than traditional orientations but generated as many patents as MPO projects. Finally, we highlight that initial research orientation is a crucial determinant variable of scientific and commercialization performances, and our paper opens rooms for further research to the literature on academic engagement, university-industry collaborations, and Collaborative Ph.D.

KEYWORDS: University-Industry collaborations, Ph.D., Academic engagement; Doctoral education.

ACKNOWLEDGMENT: We would like to thank C. Angelier (ANRT), P. Giat (ANRT), N. Sennequier (INPI), F. Caillaud (WIPO), the members of the Design Theory & Management of Innovation (DTMI) group, the participants of the track "R&D ecosystems" at R&D Management Conference Paris ed., 2019, for their helpful comments for this article. We also thank the three research engineers that were involved in the project: Maureen Vagneron, Amaury Cordier and Paul Noiret.

Working paper - Do not cite without authors' approval

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1. INTRODUCTION

Collaborations between public research laboratories and private companies are of vital interest to favor new scientific knowledge, transfer, and technological innovation (e.g. Etzkowitz and Leydesdorff, 2000; Rothaermel et al., 2007). To support those, academic have tended to be more extensively *engaged*[1] with the industry (for a global overview, see Perkmann et al., 2013; 2021) through various forms of research collaborations.

Academic engagement is widely practiced across disciplines and is of substantial economic significance both for private companies and universities (e.g. Cohen, Nelson, & Walsh, 2002; Hughes et al., 2016). Previous research puts great effort into identifying individuals (e.g. Tartari & Breschi, 2012), organizational (e.g. Johnson, Monsen, & MacKenzie, 2017), relational (e.g. Tartari, Perkmann, & Salter, 2014), and institutional characteristics (e.g. Abreu & Grinevich, 2013) conducting to greater academic engagement, as well as the consequences of such engagement on research productivity (e.g. Bikard, Vakili, & Teodoridis, 2019), commercialization potential (e.g. Lavie & Drori, 2012), and broader societal impact (e.g. Iorio et al., 2017).

Nevertheless, the consequences of academic engagement on research quality and intellectual property development's potential remain unclear (Perkmann et al., 2021), and are contingent to various research projects' characteristics (e.g. Callaert, Landoni, Van Looy, & Verganti, 2015; Rentocchini, D'Este, Manjarrés-Henríquez, & Grimaldi, 2014). While it has

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[1] To simplify, we will use the terminology "engage" always in the context of engage with the industry though research collaborations, in line with Perkmann & al. (2013, 2021) definition.

been shown that academic engagement conducts on average to higher academic productivity (e.g. Banal-Estañol, Jofre-Bonet, & Lawson, 2015; Bikard et al., 2019; Gulbrandsen & Smeby, 2005; Hottenrott & Lawson, 2017), engaged academics' scientific performances are heterogeneous at the individual level (Van Looy, Callaert, & Debackere, 2006). This latter phenomenon can be linked to the large variety of university-industry collaborative research projects' aims and settings (Carayol, 2003; Meyer-Krahmer & Schmoch, 1998). To go a step further in understanding academic engagement's effects on research projects' performances, management scholars have recently called to control for projects' research orientation (e.g. Tijssen, 2018), an issue that received less attention in the literature on academic engagement.

One the one hand, some scholars alleged that a more excellent orientation towards industry demands—ie. *market-pull orientation* (ie. MPO)—in university–industry collaborative research projects would lead to reducing academic contribution to open science and favoring the development of IP for private companies (e.g. Blumenthal et al., 1996; David and Dasgupta, 1994), when compared with more *research-push orientated* projects (ie. RPO). For example, Callaert et al. (2015), by analyzing three strategic approaches mainly used by scientists from two European Universities across their joint-research projects' portfolios, showed that when scientists do not participate in projects in response to industry's calls, they record higher scientific performances. On the other hand, even when supporting industry needs (ie. MPO), academics' research activities can be fostered by having access to companies' skills, equipment, or materials (e.g. D'Este and Perkmann, 2011; Mansfield, 1995), by increasing the pool of available new ideas for scientists (e.g. Evans, 2010; Siegel et al., 2003), and by favoring more fruitful labor division (Bikard et al., 2019). Hence, Goldstein and Narayanamurti (2018) explored another possible fruitful research orientation, based on the scientists' commitment to addressing fundamental research questions through applied research, referred to as *Simultaneous Discovery-Invention (SDIO)* research orientation (in echoes to Stokes, 1997).

As university-industry collaborations remain contentious (Murray, 2010), there is a need to better assess the relevance of those results for academic engagement in diverse contexts (disciplines, universities, etc.), at project level, and with a fine-grained control variables' set due to, as previously mentioned, the heterogeneity of joint-research projects (Callaert et al., 2015; Tijssen, 2018). Indeed, the effects of *ex-ante* research orientation on *ex-post* scientific and commercialization performances of joints research projects with the industry needs to be further assessed and still lack quantitative analysis. Our study aims to fill this gap by classifying joint research projects among different research orientations (ie. market-pull, research-push, or simultaneous-discovery-invention) at their launch, and reviewing their ex-post patenting and publication data.

To do so, we rely on an original dataset of a yet understudied category of joint-research projects: university–industry collaborative Ph.D. While Ph.D. students represent an essential part of academic research groups and are vital contributors to the development of new scientific knowledge (e.g. Baruffaldi, Visentin, & Conti, 2016; Larivière, 2012), there is recent evidence that some of them are also involved in collaborations with the industry during their training, along with their supervisors (e.g. Buenstorf and Heinisch, 2020; Gaughan and Robin, 2004). In Europe, many countries have prescribed various government-funded programs to develop *Collaborative Ph.D.* with the industry, representing large number of Ph.D. students. Nevertheless, in management science, research on Ph.D. students' contribution to science and innovation remains limited (Shibayama, 2019), and the specific study of Collaborative Ph.D. programs largely underexplored (Salimi et al., 2015a). It has to be highlighted that the managerial literature on *Collaborative Ph.D.*, while scarce, obtains findings aligned with the broader literature on academic engagement, including an overall positive effect on scientific productivity compared to traditional Ph.D. (Gaughan & Robin, 2004; Salimi, Bekkers, & Frenken, 2015a) despite heterogeneous settings of projects (Butcher & Jeffrey, 2007). We also found evidence in qualitative studies of the three distinct research orientations previously mentioned (e.g. Grimm, 2018 for MPO; Harryson et al., 2007 for SDI; Kerr and Ivey, 2003 for RPO), which make the case relevant for the review of research orientations' effects on joint projects' scientific and commercialization performances.

The paper is structured as follows: in the following paragraph, we define hypotheses derived from the literature; then we introduce the context of the empirical data, as well as the methodology used to analyze the different variables and indicators. A subsequent section covers the main results, and we then conclude by discussing theoretical implications, limitations, and room for further research.

2. THEORETICAL CONSIDERATIONS

2.1. Academic engagement: the case of Collaborative Ph.D.

While being subject to regional specificities, overall, Collaborative Ph.D. covers a research project that has "*a typical duration of 3-4 years and which involves a university, a firm and a Ph.D. candidate, all working together to meet (common or individual) expectations*" (Salimi, Bekkers, & Frenken, 2016: 813) and for which an "*industry expert take part in the supervision committee, officially and informally*" (Borrel-Damian, Morais, & Smith, 2015: 17). Hence, they can be arranged directly by the company and a public laboratory on a discretionary basis (see examples from Italy, Switzerland, Norway, or Lithuania in Borrel-Damian et al., 2015, p. 67-69). However, in many cases, and particularly in Europe, policy-makers developed specific programs to support and develop Collaborative Ph.D. programs[2]. They sometime

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[2] Collaborative Ph.D. programs with the industry include BBSRC CASE or EPRSC CASE studentships in the UK, the Enterprise Partnership Scheme (IRCSET) in Ireland, the Leaders for Technological Industries scheme in Portugal, the Graduate-Cluster for Industrial Biotechnology in Germany, the Industrial doctoral student's Project in Sweden, or the Industrial Ph.D. program in Denmark, CIFRE case in France.

represent large numbers of Ph.D. students, such as in France where 10% of the total cohort of funded Ph.D. students each year is involved in such program[3].

It is our understanding that Collaborative Ph.D. programs constitute then a modality for academic engagement (D'Este & Perkmann, 2011), that can be referred to as "*knowledge-related interactions by academic researchers with non-academic organisations, as distinct from teaching and commercialisation. These interactions include collaborative research, contract research [...]*" (Perkmann et al., 2021: 1). Indeed, Collaborative Ph.D. cannot be viewed as solely a practice to transfer or commercialize scientific knowledge, as they require overall similar scientific quality than traditional Ph.D. (Kerr & Ivey, 2003). Furthermore, Collaborative Ph.D. is a way for both Ph.D. students and academic supervisors to be involved in collaborative and contractual research projects with companies. The latter constitutes one key reason universities engage in Collaborative Ph.D. projects (Borrel-Damian et al., 2015).

As previously noted, Ph.D. students involved in Collaborative Ph.D. do not seem to suffer, on average, from a negative effect on their scientific productivity in comparison with traditional Ph.D. programs. Kerr and Ivey (2003), through a case study analysis¸ concluded that the understanding of the scientific and technical issues in Collaborative Ph.D. projects is equivalent to traditional training programs. Hence Collaborative Ph.D. projects "*entail the same high standards for scientific quality of research as that required of a doctorate in a traditional doctoral programme*" (Borrel-Damian et al., 2015: 8). Gaughan and Robin (2004), by conducting a survey and CV analysis on 807 Ph.D. in life sciences and physics concluded that being engaged in the CIFRE Collaborative Ph.D. program in France, does not affect student's publication productivity. Salimi et al. (2015), through an analysis of 448 Ph.D. students at Eindhoven University of Technology, showed that, on average, students involved in Collaborative Ph.D. research projects obtained better performances in terms of the number of

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[3] French National Audit Court Data (2018), Report on the *Investment Plan for the Future* (PIA)

scientific publications and number of publications' forward citations than other students[4]. Overall, those findings match with results from the academic engagement literature: one consequence of engagement with the industry is, on average, an increase of scientific productivity at individual level (e.g. Bikard et al., 2019; Tijssen, 2018).

In terms of intellectual property generation and contribution to firms' innovation processes, Salimi et al. (2015) showed that Ph.D. students involved in Collaborative Ph.D. projects recorded better performances than those who do not, in terms of the number of filed patents and number of patents' forward. Furthermore, Buenstorf and Heinisch (2020) analyzed the contribution to firms' innovation processes of recently graduated Ph.D. in the context of the German laser industry. Using topic-modeling techniques to compare Ph.D. dissertations and patents that Ph.D. holders filed for companies' accounts, they found out that some of them were filed while the inventor was still a Ph.D. student due to collaborative research projects. Focusing on those "*early patent[s]*" (Buenstorf & Heinisch, 2020: 4), they demonstrated that they were, on average, more exploratory regarding a given company's patent portfolio. This finding conducted them to claim that having an early access to new scientific knowledge developed by Ph.D. students is crucial for companies' innovation performances. Finally, those two studies are also in line with results from the academic engagement literature suggesting that engagement with industry increases academics' inventive prowess measured by patents (e.g. Lawson, 2013).

Collaborative Ph.D. projects differ in terms of settings, goals, and characteristics (e.g. Butcher and Jeffrey, 2007; Salimi et al., 2015b). While they are associated on average to greater scientific performances, performances at the project level are heterogeneous (Tavares, Soares, & Sin, 2020). Similarly to more traditional university-industry collaborative projects, one key,

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[4] It has to be highlighted that the study was performed in a particular context as the University was extensively relying on this particular scheme (ie. 1/3 of its Ph.D. students). Moreover, lots of projects were conducted with a unique large regional industrial private company.

but understudied, explanatory factor might be embedded in the choice of projects' research orientation (Callaert et al., 2015; Tijssen, 2018), that has to be analyzed by reflecting to the broader literature on academic engagement. We acknowledge that relying here on collaborative Ph.D. instead of traditional university-industry collaborative projects do not conduct to significant bias regarding research orientation, as in most collaborative Ph.D. program, the Ph.D. supervisor is highly involved in the project.

2.2. Collaborative Ph.D. and research orientations

This section discusses possible research orientations in Collaborative Ph.D. projects and their effects on subsequent scientific discoveries, commercialization potential, and possible joint-outcomes (ie. at least one publication and one patent) through a given project.

2.2.1. Market-pull (MPO) and Research-push (RPO) research orientations

Market-pull-oriented (ie. MPO) collaborative Ph.D. projects are based on conducting research on the companies' products, processes, or services in relation to companies' R&D short-term goals, needs, or issues[5]. Conversely, *research-push-oriented* (ie. RPO) projects are more oriented towards creating novel basic scientific knowledge[6]. Those two research directions are mostly presented as opposed to one another.

In terms of performances, MPO research projects are mainly considered as less prone to favor new scientific discoveries but tend to lead more often to commercialization through patenting (e.g. Bush, 1945; Calderini, Franzoni, & Vezzulli, 2007). Some examples of both research directions were found when reviewing the literature on Collaborative Ph.D. (e.g. Grimm, 2018 for market-pull; Kerr and Ivey, 2003 for research-push). Overall, MPO projects

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[5] Those projects are equally called applied-oriented (Tijssen, 2018) or non-proactive strategies (Callaert et al., 2015).

[6] Those projects are equally called discovery-oriented (Tijssen, 2018) or proactive strategies (Callaert et al., 2015)

are more frequent in university-industry interactions (Mansfield, 1998; Muscio & Pozzali, 2013) as it would be easier for firms to absorb more applied knowledge (Bruneel, D'Este, & Salter, 2010; Nooteboom, Van Haverbeke, Duysters, Gilsing, & van den Oord, 2007). This phenomenon might be amplified in Collaborative Ph.D. projects due to companies' bargaining power in providing financing for the project (Slaughter & Campbell, 2002). Here, we will detail factors explaining those projects' performances in relation to the two identified research directions in the context of Collaborative Ph.D.

First, when external funding requirements shape the content of a research project (ie. MPO projects), it has been showed that scientists involved record lower scientific performances due to less incentive to explore novel lines of inquiry (Azoulay, Graff Zivin, & Manso, 2011). In the context of Ph.D. students, Broström (2019), analyzing survey results related to the 2006 cohort of Ph.D. students in Sweden, confirmed this result. Notably, he highlighted that "there exists a trade-off between two potential objectives: to "*get what you want*" in terms of research content and to foster academically successful PhDs" (Broström, 2019: 1656). As in MPO Collaborative Ph.D. projects, content and objectives are extensively shaped by the company, it supports the detrimental effect of Ph.D. student scientific performances compared to RPO Collaborative Ph.D. projects, which might be more extensively shaped by Ph.D. students and Ph.D. supervisors.

Second, Collaborative Ph.D. students may act as "gatekeepers" (Thune and Børing, 2015, p. 641) between universities and industries, particularly in MPO projects for which key objectives would be transferring and adapting public laboratory's knowledge to the industry context. Those Ph.D. students might have to spend time and effort for other purposes than research activities (problem-solving for the companies, business analyses, etc.), activities that have been shown to negatively impact scientists' production of new academic knowledge

(Toole & Czarnitzki, 2010). Conversely, adapting public laboratory's knowledge to the industry context can boost patenting in those MPO research projects, compared to more RPO ones.

Third, Collaborative Ph.D. students are on average more prone to take a position in the industry at project completion (Mangematin, 2000; Thune & Børing, 2015), or to engage in an entrepreneurial activity through start-up creation (Muscio and Ramaciotti, 2019). Hence, they might tend to self-select more in MPO projects as their commitment to producing breakthrough science might be lower than acquiring business knowledge, as shown by Grimm (2018) in the context of the German automotive industry.

Four, in MPO, companies can be more prone to implement publication barriers restricting or delaying publications as it has a direct impact on their innovation portfolio (Blumenthal et al., 1996; Czarnitzki, Grimpe, & Toole, 2015), which can ultimately impact the scientific productivity of involved Ph.D. students compared to RPO projects.

Based on those findings, we then derived the following:

- **Hypothesis H1.** Ex-ante RPO research direction in Collaborative Ph.D. projects would result in ex-post greater scientific performances than MPO projects.
- **Hypothesis H2.** Ex-ante MPO research direction in Collaborative Ph.D. projects would result in ex-post greater patenting performances than RPO projects.

2.2.2. Simultaneous discovery-invention (SDI) research orientation

Another possible research orientation in collaborative Ph.D. projects lies with the Pasteur quadrant logic (Stokes, 1997), by intersecting basic research and an interest in the discovery's usage. There are qualitative observations that the cycle of discovery–invention is not always linear (Godin, 2006; Narayanamurti & Odumosu, 2016; Narayanamurti, Odumosu, & Vinsel, 2013). Hence, Goldstein and Narayanamurti (2018) studied the performances of research projects committed to address technological issues that are too novel to be considered as applied ones (Goldstein & Narayanamurti, 2018: 1507). To do so, they analyzed projects from a specific branch of the US Department of Energy, the Advanced Research Projects Agency–Energy (ARPA-E), which aims to support such projects. They compared performances of ARPA-E projects with those from other divisions: the Energy Efficiency and Renewable Energy (EERE) branch, which usually financed applied-oriented projects (ie. MPO), the Office of Science, which usually financed basic-research (ie. RPO). They showed that projects of ARPA-E record higher performances than projects from the other branches in terms of joint output of patents and publications. We found one example of this strategy in qualitative work on Collaborative Ph.D. in Harryson et al. (2007). We would push this line of research forward by testing how simultaneous discovery-invention (SDI) research direction would perform in the context of Collaborative Ph.D. projects. We made then the following hypothesis (**Hypothesis H3**):

- **Hypothesis H3.** Ex-ante SDI research direction in Collaborative Ph.D. projects would result in ex-post greater joint output (scientific publication and filed patents) performances than MPO or RPO project's direction.

3. METHODOLOGY

3.1. Context: the CIFRE program

To test our hypotheses, we relied on an original dataset regarding collaborative Ph.D. projects, started in 2015, and conducted through the *Industrial Convention to Research Training* (CIFRE) Collaborative Ph.D. program (then called "CIFRE program") in France.

The CIFRE program was established in France in 1981 and aims at "*financially support a company operating through the French legislation, to recruit a Ph.D. student that will be at the heart of a joint research project with a public laboratory. The research works of the joint-*

research project have to support the preparation of the Ph.D. student's defense"[7] (ANRT, 2018: 25). The *National Agency for Research and Technology* (ANRT), a not-for-profit organization that acts on behalf of *the French Ministry of Higher Education, Research, and Innovation* (MESRI), supervises the CIFRE program. In 2015, after 35-years of operation, the CIFRE Ph.D. program trained 25,400 Ph.D. students in 8,500 different companies and involved 4,000 different public laboratories. The CIFRE program has become more and more attractive each year since its creation. In 2000, 750 CIFRE Ph.D. projects were launched while 1,383 started in 2015, the latter representing 10% of all the Ph.D. students' cohort in France that year.

In the CIFRE Ph.D. program, the company, the public laboratory, and the Ph.D. student are all contractually tied (**Figure 1**). First, the company–from large companies of over 5,000 employees to SMEs of less than 250 employees–has to hire the Ph.D. student through a 3-year employment contract (or a permanent contract) at a minimum annual gross wage of 23,484€ (2015 figure). Second, the Ph.D. student has to be enrolled in the University[8] from which the public laboratory belongs. The Ph.D. student and the public laboratory are tied with a Ph.D. agreement, which details the conditions of the research, the registration conditions, rights, and duties of the Ph.D. students to obtain the Ph.D. diploma in the University. It has to be noted that the program also attracted 21% of foreign Ph.D. students in 2015. Third, the public laboratory and the company are tied with a 3-year Contractual Agreement. While there is no specific framework, usually, the following sections are included in the Contractual Agreement: characteristics of the parties, workplace arrangements for the Ph.D. student (including time to be spent in each facility), financial arrangements, intellectual property conditions, and litigation and termination arrangements. Usually, the company contribute financially to the supervision of the Ph.D. student by the public laboratory. Moreover, a specific Appendix in the Contractual

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[7] Translation from French to English by the authors.

8 We used the general term "University" here, but due to the French higher education system's specificities, it also includes Grandes Ecoles and other Higher Education institutions such as business or engineering schools.

Agreement contains a research project summary at the beginning of the joint research project. ANRT supports the research by providing the company with a 14,000€ subsidy each year during the project's three-year duration, on a budget made available by the MESRI.

Figure 1 - Parties and institutional ties of a CIFRE collaborative Ph.D.

One key element of the CIFRE program is that the parties are set free to define the joint research project goals, orientations, content, field of research[9] and expected outcomes as long as the research work serves the Ph.D. dissertation and conduct the student to be graduated with the Ph.D. diploma at completion. Hence, the public laboratory and the company are able to negotiate the Contractual Agreement that is the most suitable for the project. For example, the time to be spent by the Ph.D. student in a given facility during the three years can be divided from 0% to 100%, intellectual property can be fully appropriated by one of the parties or shared between them. Nevertheless, to be eligible for the CIFRE program, the parties have to complete an application including details on their characteristics, conditions of the project (e.g. time spent by the Ph.D. student in each facility), and the research project's summary. ANRT evaluates the joint-research project eligibility to the CIFRE program, in particular based on an expert assessment of the project. The latter, which is typically made by a university professor in the field of the research project, focuses on the "*scientific value of the project*" and "*the selected Ph.D. student's adequacy with the project's goals*" (ANRT, 2019a: 4) The acceptance rate for a CIFRE Ph.D. project by ANRT is 90%.

ANRT is also performing an ex-post evaluation of the projects through dedicated surveys that are separately sent to the Ph.D. student, to the Ph.D. supervisor in the public laboratory, and to the Ph.D. supervisor in the company upon project completion. Those surveys

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[9] The program is funding projects in any scientific disciplines (engineering, social sciences, mathematics, etc.), but in 2015, Information and Technological Science Technologies (22%), Engineering Sciences (20%), and Chemistry & Materials (12%) are the top-3 scientific disciplines among the CIFRE project.

include elements regarding the project management (e.g. number of meetings between the parties, potential conflict regarding the research orientation), and the performances (e.g. number of top journal publications, number of filed patents by the company related to the project).

Regarding our research question, the CIFRE Ph.D. program is highly suitable to test our hypotheses as the program is not oriented towards a particular field or scientific discipline, involved diverse universities and companies, and does not favor a specific research direction. Indeed, the CIFRE Ph.D. program supports projects oriented towards a "*fundamental approach*" (ANRT, 2020: 9) (ie. research-push); the development of "*technological disruption*" (ANRT, 2019b: 2) or aiming at "*anticipating future technology*" (ANRT, 2020: 9) (ie. simultaneous discovery-invention), or the "*development of an competency to solve [company's] complex problems*" (ANRT, 2020: 10) and "*transfer and value [public laboratory] research"* (ANRT, 2020: 9) (ie. market-pull). We also highlight that due to the specific settings of Collaborative Ph.D. in the CIFRE program (e.g. contractual agreement between the public laboratory and the company), those projects are representative of traditional university-industry research collaborations and do not appear biased by the fact that it also implies the Ph.D. dissertation completion.

3.2. Data

In this study, we relied on a unique dataset of Collaborative Ph.D. projects launched in 2015 through the CIFRE Ph.D. scheme in France. For each of those projects, the data includes:

- Details from the Application Form completed by the parties to apply for the CIFRE program (e.g. number of employees of the companies, Nationality of the Ph.D. student, geographical location of the facility);

- The Contractual Agreement (and its Appendix related to the research project summary) negotiated between the public laboratory and the company before the beginning of the project (e.g. intellectual property terms, a summary of the research projects);
- The three post-project surveys completed by (1) the Ph.D. supervisor in the public laboratory, (2) the Ph.D. supervisor in the company and (3) the Ph.D. student (e.g. number of patents filed by the company along with the project, number of academic publications, number of inter-parties meetings, potential conflicts occurring during the project).

The sample was restricted to projects for which sufficient data were available (particularly, three completed post-CIFRE surveys and a comprehensive project summary), representing 635 Ph.D. projects.

The key independent variables of interest, related to the ex-ante research orientation, were computed following a qualitative analysis of the research project summaries included in the Contractual Agreement's Appendix (see next subsection for dedicated procedure). To control for characteristics of the different projects, we extracted 25 control variables from the Application Forms, Contractual Agreement, and the post-CIFRE surveys. Dependent variables were extracted from the post-CIFRE surveys based on self-reported (1) number of scientific publications, (2) number of scientific publications in top-journal, (3) number of filed patents by the company with the project, (4) Ph.D. Prize received as an award by Ph.D. student at project completion. Besides, to measure performances, we also explore joint outcomes (Goldstein & Narayanamurti, 2018).

3.3. Procedure to derive research orientation

Exploring the role of research directions on projects' performances is a challenging task. Scholars mainly relied, as a proxy for orientation towards MPO (or applied-research), to an *ex-post* evaluation of the project's outcomes. For example, scholars reviewed to what extent scientific papers published in relation with a given project was cited in any patent (see the usage of scientific non-patent literature, for example in Marx and Fuegi, 2019), the type of journal in which scientific papers were published classified by the number of scientists affiliated to a private company that are publishing in that specific journal (e.g. Tijssen, 2012), or the number of patents filed in the project's context (e.g. Bikard et al., 2019). Others relied on proxy closer from an ex-ante analysis of the research direction. For example, Callaert et al. (2015) used survey data to distinguish between different research orientations in the portfolio of scientist's projects. Goldstein and Narayanamurti (2018) relied on the projects' belonging towards the US Department of Energy‘s different departments to derive research orientations, Azoulay et al., (2011) to projects' belonging towards either Howard Hughes Medical Institute or National Institutes of Health. However, having *ex-ante* information on projects' research orientations would be critical to assess the effect on projects' performances. Therefore, our original dataset contains projects' summaries at project launch that can be qualitatively analyzed to derive the research direction of the project.

To do so, we classified research projects' summaries enclosed in the Contractual Agreement according to three distinct research directions: (1) research-push, (2) market-pull and (3) SDI, by using a qualitative approach. The methodological process is detailed below and summarized in a flow chart (**Figure 2)**.

Figure 2 – Research strategies methodology implementation.

During a *pre-study phase* focusing on analyzing 70 research projects' summaries from various years provided by ANRT (excluded from the final dataset), the authors defined a list of criteria to classify each research project according to the three possible research directions. Then, we relied on a structured sample of 909 Contractual Agreement (and associated Appendix with projects' summaries) for CIFRE Collaborative Ph.D. projects launched in 2015 and which all have been completed (ie. no project terminated before completion). ANRT randomly selected projects for the purpose of the study by keeping the share of SMEs equal in the sample compared to the total number of CIFRE Collaborative Ph.D. launched in 2015 (43.2% in the sample, 43.9% in the total population). During the *training phase*, the research team trained three qualified research engineers to classify 200 projects according to the three research directions. The authors coded the first 40 projects and then discussed them during two meetings of approximately 2 hours with the research engineers to teach them the methodology. 160 other projects were then double-coded independently by the research engineers, and separately by the authors. The research engineers' results were discussed during regular meetings with the authors to ensure full appropriation and harmonization of the methodology. Based on their feedback, the list of criteria to classify projects was also iteratively updated and stabilized at the end of this phase. During the *Coding Phase*, the three research engineers double-coded independently and separately the 709 remaining research projects. During the *Training-set coding phase*, the 200 research projects from the training phase were each coded once another time by the research engineers to ensure the consistency of the approach. Overall, the *Coding Phase* procedure led to similar codes in over 70% of the final sample projects. In a final *Harmonization phase*, the authors reviewed each project's summaries coded differently by the research engineers to define the most suitable research orientation (always among the two categories identified by the research engineers), based on verbatim extracted by the engineers to make a decision. Finally, we were able to classify 748 projects (82% of the dataset), as some missing or incomplete Appendix were discarded (e.g. only recto pages scans while the Contractual Agreement was printed on recto-verso). We also discarded the projects for which the three ex-post surveys were not available (15%), and we ended up with 635 projects in our final dataset.

The detailed criteria for each research direction were defined iteratively in relation to the CIFRE project context in order to operationalize the three identified research directions. There is no particular framework for the research summary enclosed in the Contractual Agreement, and the Parties are free to include the document that most suits them. On average, it is a document written in French, in most cases of around 3 to 5 pages that present the context of the project (discipline, key challenges, etc.), the key expertise of the public laboratory and the company for the project, a brief literature review, the research questions, the envisioned methodology and the workload of the Ph.D. student. The final coding criteria and some examples are provided in **Table 1**[10].

Table 1 – Research direction coding criteria and examples.

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4. RESULTS

4.1. Descriptive statistics

Variables' description is presented in **Table 2** and we also provide a descriptive statistics analysis in **Table 3**. Looking at our sample, first we identify that the three categories of research orientations are not equally represented. While it is mainly assumed that Collaborative Ph.D. projects would be prone to favor MPO projects due to companies' bargaining powers (e.g. Grimm, 2018; Slaughter and Campbell, 2002), it is not the case in our sample. Hence 60% of the projects are RPO, and 27% MPO, while 13% only are SDI.

Table 2 - Summary of variables used.

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[10] Due to confidentiality issues, company names are anonymized.

When focusing on projects' performances, first, Collaborative Ph.D. projects with an orientation towards SDI, on average, better perform than MPO or RPO projects. They lead to a higher number of output per project and are also more likely to obtain at least a publication (86.3% of projects) or a joint-output (21.3% projects), even when considering top-journal publications only (16.3%). By using a t-test analysis with unequal variance, we show that the difference in means between SDI projects and projects with other research orientations projects are greater on all measured outputs at 99% confidence (**Appendix A1**). Second, we also observe that MPO projects better perform than RPO in terms of IP production, but lead to similar results in terms of scientific output (including for top-journal publications).

Table 3 – Summary statistics

Nevertheless, those results are only descriptive. We need to control both the projects' characteristics (e.g. type and size of companies) and conditions of completion (e.g. conflict occurrence, frequency of meetings) of the Collaborative Ph.D. projects as they might influence project's performances, and the three types of research orientations are dissimilar regarding control variables. For example, MPO projects are more conducted by start-up companies, universities non-Paris area-based, universities with more significant experience working with industry, candidate less science-oriented and, by a higher share of foreign Ph.D. candidate.

4.2. Estimation

4.2.1. Estimation strategy

To measure the influence of ex-ante research directions on scientific discoveries and invention, we adopt a similar estimation strategy to Goldstein and Narayanamurti (2018). Hence, we measure first the influence of research directions on the likelihood to obtain both outputs jointly, and we then analyze in more depth each scientific and innovation outputs separately. To consider the characteristics and conditions of projects' completion, we rely on a set of 25 unique control variables. We model the probability of binary output variables using both logistic regression and linear regression (**Equation 1**). Y_{ij} is the outcome of the project *i;* X_i the research orientation (SDI, MPO, RPO); φ_i a vector of control including the 25 control variables, ω_j a fixed effect for the research orientation type.

$$logit\left(P(Y_{ij})\right) = \beta_0 + \beta_1 X_i + \beta_2 \varphi_i + \omega_j$$

Equation 1

Figures from logit regressions in tables are exponentiated coefficients that correspond to the odds ratio for obtaining a giving outcome (e.g. at least one top-journal publication), compared to the two other types of research orientations (except for linear regression models used for control purposes). To consider count variables (e.g. number of top-journal publications per project), we model the expected value by using negative binomial regression. In those models, exponentiated coefficients are incidence rate ratios compared to the two other types of research orientations. Due to the considerable heterogeneity in project performances per discipline (see **Appendix A2**), robust standard errors are clustered at discipline level. In the table below, we test three model specifications: a first with no control variables, a second with only control variables highly and significantly correlated to one of the project direction types, a third one with the full set of control variables.

4.2.2. Joint output performances

As Collaborative Ph.D. programs mainly claim that they favor both scientific and innovative impacts, it is interesting to beginning our analysis by reviewing the probability of getting a joint output through the CIFRE program (ie. at least one scientific publication, and one patent). Descriptive statistics indicate that obtaining both a publication and a patent remains a rare event, on average roughly in one project out of ten. Nevertheless, RPO projects, on average, underperform when looking at this criteria (9.9% of the projects), while MPO and SDI projects lead to approximately similar results (20.0%).

First, estimations' results (**Table 4**) show that SDI projects have odds ratios closer to one when compared to MPO projects, and the ratios are non-statistically significant (at $p < 0.1$ level). We interpret the latter result as that MPO projects are as likely as SDI projects to generate at least one journal publication and at least one patent. Those results hold when taking into account top journal publications only.

Table 4 – Joint output in CIFRE Ph.D. collaborative projects

Regression analysis also show that RPO projects are less likely to generate at least one journal publication and one patent than MPO projects (**Table 4**). Hence, the odds ratios are significantly lower than 0, which matches the linear model's sign. The latter OLS model indicates that RPO projects have a 7.1% lower probability of generating both outputs compared to MPO projects. Again, those results hold when considering top journal publications only (see **Appendix A3**).

Therefore, we reject **Hypothesis H3** as MPO projects are as likely as SDI ones to lead to joint outputs, and the letter research orientation is not strictly over performing other project types when considering this criteria. As we only take into account the likelihood to obtain at least both output, we need to analyze in more depth each type of output separately.

4.2.3. Scientific performances

One of the key goals is to review the performances in terms of scientific outputs of Collaborative Ph.D. projects according to their research orientation. In particular, many projects ended up with at least one publication at completion (77.5%). However, SDI projects are more likely to produce at least one scientific publication, and the number of publications per project is higher than for other strategies (2.9 vs. 2.2). Those differences are still at play when focusing on top-journal publications only (1.3 vs. 1.8) or Ph.D. prize. The difference in terms of scientific performances between MPO and RPO projects appear limited in the descriptive statistics.

Regression analyses confirm those results. SDI projects are more likely to generate at least one publication than other projects at the highest confidence level (**Table 5**). Hence, the odds ratio of producing at least one publication for SDI projects is strictly superior to one with all model specifications. In those projects, Ph.D. candidates also tend to publish more scientific papers than for any other research direction, as shown in the Negative Binomial estimations. Those results also hold for top-journal publications, with even a greater and more significant effect on the number of published papers (see **Appendix A4**). As a robustness check, we also used as a dependent variable the probability of the Ph.D. student to receive an award at project completion. We found similar results than for publications (see **Appendix A5**).

Table 5 – Scientific publication output in CIFRE Ph.D. collaborative projects

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On the opposite, the comparison between RPO and MPO projects is less straightforward. When focusing on all scientific publications only, RPO projects seem to be more likely to generate at least one publication than MPO ones, but with a low level of statistical significance, and the result does not hold for top-journal publications nor the probability to obtain a Prize at project completion. Indeed, the odds are roughly equal to one and are non-statistically significant (at $p<0.1$) for both top journal publications and awards. When focusing on the number of published papers, performances between both types of projects' directions are similar as the odds ratios are also roughly equal to 1, and the difference is non-statistically significant, with similar results for top-journal publications. Hence, we reject **Hypothesis H1** as MPO projects have overall similar scientific performances than RPO ones.

4.2.4. Patenting performances

In this section, we review the performances in terms of filed patents by the company in relation to the Collaborative Ph.D. projects, depending on the research directions. We adopt a similar approach to scientific outputs.

First, descriptive statistics show that, on average, filling a patent during a RPO project is a rare event. The company file at least one patent in only one project out of ten, a much lower number than for other projects' orientations. Estimations confirm this result (**Table 6**). Both odds ratios and incidence rate ratios are significantly lower than zero when considering both the probability of filing at least one patent or even the number of filed patents, at the highest level of significance.

Table 6 – Patent output in CIFRE Ph.D. collaborative projects

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In comparison, descriptive statistics showed that, on average, SDI and MPO projects lead roughly to a similar number of filed patents: around one project out of four filed at least one patent. Results from estimation showed that SDI projects have roughly the same odds of generating at least one patent as the MPO projects, and results are not statistically significant. Furthermore, we showed that SDI projects tend to generate more patents on average than the others type of projects according to the incidence rate ratios. However, results are only statistically significant at $p<0.05$ level. Hence, we accept **Hypothesis H2** as MPO projects are likely to lead to higher patenting performances than RPO ones.

5. DISCUSSION

In this paper, we review how university-industry research projects' scientific and commercialization performances are contingent on their initial research orientation (MPO, RPO, or SDI) in the context of the CIFRE Collaborative Ph.D. program in France. We claim that research orientation is a crucial variable, highly significant to determine a project's performances despite a large control variables' set. First, our analysis confirms the straightforward hypothesis that when a university-industry research project has an orientation towards industry needs, it develops more IP than projects oriented towards research push objectives. However, orientation towards industry needs leads to similar scientific performances as in projects oriented towards scientific discovery. Third, while projects with an orientation towards simultaneous discovery-invention were claimed to be more performant than others, we show that in the CIFRE program context, they record higher scientific performances but similar commercialization performances than projects oriented towards industry needs. As a result, similar performances between those two research orientations are observed in terms of the likelihood to generate joint-output.

Our findings contribute to the literature on academic engagement in two main ways. First, while engagement with the industry is considered important in various disciplines, contexts, and geographies, there was very little evidence on engagement at the Ph.D. training stage. Indeed, senior scientists were considered to be more prone to engage as they are able to share expertise that had been cumulated after years of research (e.g. Levin & Stephan, 1991; Schuelke-Leech, 2013). Hence, in the context of the CIFRE program, we showed that some Ph.D. students might be very successful in producing novel scientific knowledge, with potential for commercialization through academic engagement. While it is now clearly established that there is a positive relationship between academic engagement and scientific productivity (see Perkmann et al., 2021, 2013), and because engagement is engendered by previous engagement, early positive exposure to the industry can be considered as promising for those (future) academics and open rooms for further studies. In particular, reviewing how the particular set of those types of collaboration could favor transfer of specific competencies from the Ph.D.

supervisor to the Ph.D. students regarding how to scientifically manage those collaborations could be of interest. Second, our results complement those from Callaert et al. (2015) who showed that the scientific performance of scientists engaged with industry was contingent on the scientists strategies. Furthermore, while Goldstein and Narayanamurti (2018) showed that SDI research orientation was very effective in the US Department of Energy's particular institutional context, we extend those results by showing its effectivity into a broader range of university-industry projects. We hope that our contribution will encourage others to investigate this understudied area, in other geographical or institutional contexts or through qualitative studies.

Our paper also contributed to review the performances of MPO projects from a broader university-industry collaboration perspectives. Those projects are often viewed as a risky strategy for the global scientific ecosystem as applied research is often not considered as fruitful as basic research (e.g. Toole & Czarnitzki, 2010). But our results strengthen theoretical views that focusing on a company's product, process, or service as a starting point of the research activity can leverage access to original knowledge components that could be combined with more traditional research elements to favor breakthrough discoveries (Fleming & Sorenson, 2004). Learning form the industry is mainly the primary motivation of academic engagement (D'Este & Perkmann, 2011; Lee, 2000; Siegel, Waldman, & A. Link, 2003) and focusing on companies' products, processes or services can conduct the company to be more involved in the research and then favor a significant labor division with academics (Bikard et al., 2019). Further studies may focus on disentangling those effects and exploring why MPO projects lead to such scientific outcomes.

Our findings also contributed to the literature on Ph.D. students' training. Indeed, we extend Buenstorf and Heinisch (2020) finding that the early access to Ph.D. research can be of importance for firms. Indeed, companies involved in Collaborative Ph.D. projects, and particularly, when relying on SDI or MPO research directions, can filed patents directly related to the project. As some projects led to joint-output, it may favor inventions based on cutting edge research. Our contribution also echoes Butcher & Jeffrey (2007) as results obtained from the analysis of the control variables call for additional research on how to favor interactions with start-up companies in Collaborative Ph.D. projects without harming the Ph.D. student scientific productivity.

Finally, our study is subjected to some limitations. First, it relies on a specific Collaborative Ph.D. program, involving a company's financial subsidy for the research, and an in-depth review of the project's content that ensures a certain level of selectiveness, a variable associated with more significant research performances (Callaert et al., 2015). Studying other Collaborative Ph.D. programs, which do not imply such a level of research commitment, would be of interest. Furthermore, some Ph.D. students might be engaged with the industry without being involved in such a program and it would be interesting to compare their scientific and inventive outputs. Second, our approach to compute strategy is based on a careful, at least double-blinded analysis following criteria that we set for the study. Further research may be conducted to define more fine-grained strategies at play in such university-industry collaborations. Third, data regarding performances were self-reported, and are based on a limited proxy of scientific and inventive contributions: patents and scientific publications (e.g. Jaffe & de Rassenfosse, 2010). Additional studies can be conducted to review how new scientific knowledge was absorbed by the company and how a given Collaborative Ph.D. project contribute to the company's innovation process. Fourth, while we control (based on the survey), on whether or not the company or the university was already involved in the CIFRE program, we were not able to control for the complete picture regarding to what extent their innovation process relies on the CIFRE program. Indeed, companies more largely involved may adopt a portfolio approach with projects covering the three types of strategies.

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7. FIGURES & TABLES

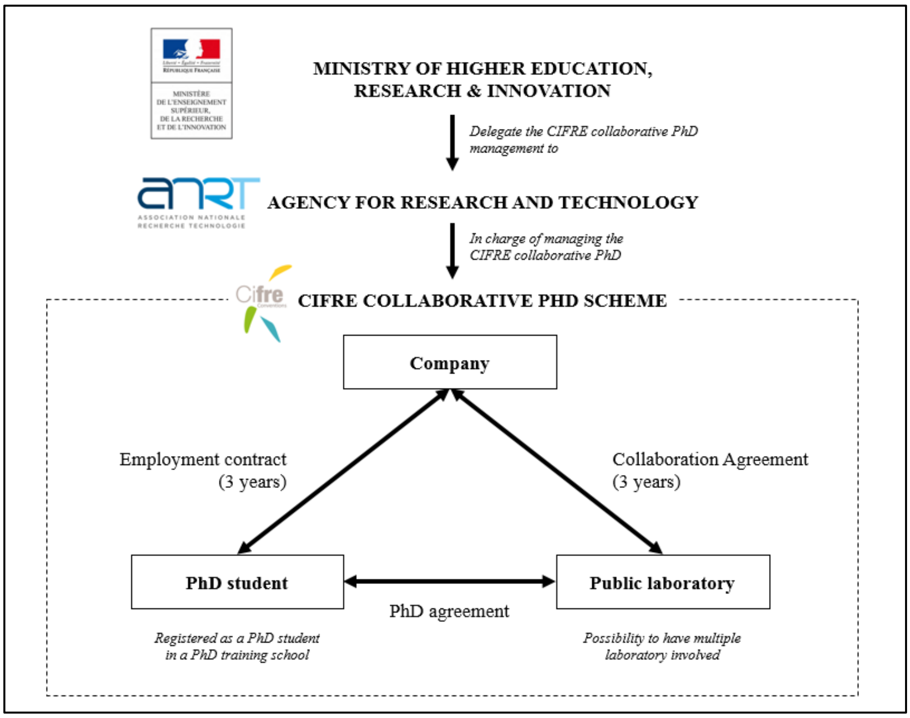


Figure 1 – Parties and institutional ties of a CIFRE Collaborative Ph.D.

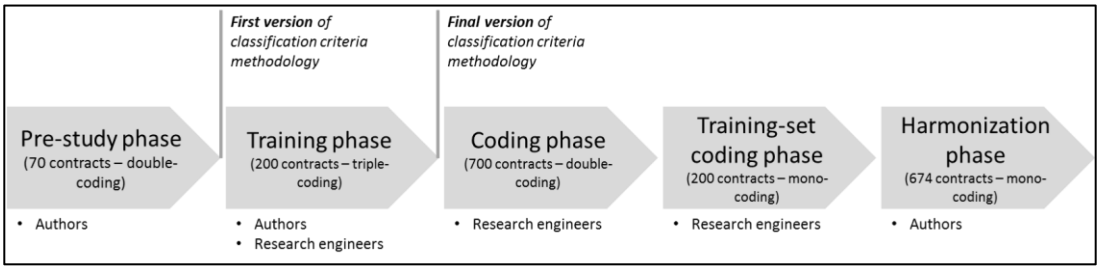


Figure 2 – Research strategies methodology implementation

	Definition	Criteria	Example
Research-push-oriented-direction (ie. RPO)	The research project is dedicated to developing new fundamental scientific knowledge in a strictly defined disciplinary area and that could aim to strengthen the company’s scientific competencies.	- There is only one scientific discipline mentioned in the project (eg. material chemistry, organic chemistry, computer science) with detailed existing literature and an identified precise scientific gap; - There is no existing precise product, process or service of the company that constituted the core of the research project; - It mainly includes projects focusing on (1) producing new scientific modeling and simulations, (2) establishing new scientific methodologies and chemical processes, (3) gathering data in the context of the company for social science projects but not directed towards implementation; - The project goal can be to develop a prototype only if is constituting a proof of concept of a fundamental research experiment.	Project #0421 between Company A, operating in the defense area, and INSA (an engineering school) focuses on a new family of explosive called “insensible”. The scientific gap is that the mechanical deformation and rupture modes during the explosion are yet unknown. The scientific goal is to define a new scientific methodology to model mechanical deformation. Here, we acknowledge that the project is not focusing on a particular product but a generic one.
Market-pull-oriented direction (ie. MPO)	The research project is dedicated to developing new academic knowledge directly applied to a pre-existing product, process, or service of the organization.	- The research project focuses on a particular product, process, or service already existing (or at the final development stage) in the company and is explicitly mentioned in the project’s summary. Research focusing on generic products are not considered here (e.g. airplane motors in general vs. the airplane motor X2589 for A321 aircraft); - Or, the research project is focusing on developing a new product that can be directly commercialized at the end of the project. - The project goal can be to develop a prototype, except if the prototype aims at being a proof of concept of a fundamental research experiment; - Social sciences projects for which the core objective is to design a new process directly implemented in the company and scientific literature is abundant according to the research summary would be considered in this category.	Project #0456 between Company B, producing tools for the beekeeper’sindustry, and Tours University focuses on developing a new trap for *Vespa Velutina Nigrithorax*, a sort of hornet. The company already conducted a project to develop scientific knowledge on this particular hornet. The project’s objective is first to leverage scientific techniques to identify biotic parameters that would attract or be a repulsive for the hornet. Second, the project aims at designing a trap to capture the hornet that can be directly commercialized at project competition.
Simultaneous-discovery-invention-oriented direction (ie. SDI)	The research project is dedicated to developing new scientific knowledge regarding the investigation of radically new scientific areas, transdisciplinary contexts-, or very disruptive industrial contexts.	- The research project can be transdisciplinary as more than one scientific discipline is mentioned in the project (e.g.: philosophy and medicine) or there is at least two public laboratories focusing on different areas involved; - The research project can be embedded in a radically innovative context which requires the development of new scientific methodology or new knowledge to tackle a new level of constraints (ie. the scientific gap includes to tackle many large challenges); - The research project can focus on the development of new knowledge in a very new scientific disciplines; - The project is not a follow-up of a previous company exploration (in particular with commercial objectives);	Project #0593 between Company C, producing numerical and video systems for the media industry, and focuses on developing innovative paths related to the display of images enhanced with tactile sensations. There are multiple scientific challenges to be tackle in the novel discipline called haptic. In particular, one objective is to be able to feel the sensation of a blue jeans by touching a screen.

Table 1 – Research directions coding criteria and example

Variable	Definition
SDI project	A dummy variable equal to 1 if the CIFRE Ph.D. project is considered as SDI; 0 otherwise.
RPO project	A dummy variable equal to 1 if the CIFRE Ph.D. project is considered as research-push-oriented; 0 otherwise.
MPO project	A dummy variable equal to 1 if the CIFRE Ph.D. project is considered as market-pull-oriented; 0 otherwise.
Comp. nbr. employees	Number of employees in the private company partner as declared by the Parties to ANRT at the beginning of the Ph. D. project
Comp. R&D dpt.	A dummy variable equal to 1 if the private company already has a structured R&D department as declared in the post-CIFRE company survey; 0 otherwise.
Comp. Start up	A dummy variable equal to 1 if the private company is considered as a start-up company as declared in the post-CIFRE company survey; 0 otherwise.
Comp. nbr. Ph.D.	The number of employees with a Ph.D. as declared in the post-CIFRE company survey; 0 otherwise.
Comp. Paris area	A dummy variable equal to 1 if the private company facility, in which the Ph.D. Candidate is involved, is located in the Paris Region, as declared by the Parties to ANRT at the beginning of the Ph. D. project; 0 otherwise.
Comp. excl. IP	A dummy variable equal to 1 if the private company has exclusive IP rights on the outcome of the Ph.D. project, as stipulated in the contractual agreement between the private company and the University; 0 otherwise.
Comp. first CIFRE	A dummy variable equal to 1 if the private company participate in the CIFRE program for the first time, as declared in the post-CIFRE company survey; 0 otherwise.
COMPMASTERED	A dummy variable equal to 1, if the private company looked for developing new scientific knowledge on a domain that is already mastered by the company through the CIFRE Ph.D. project, as declared in the post-CIFRE company survey ; 0 otherwise.
COMPNEW	A dummy variable equal to 1, if the private company looked for developing new scientific knowledge on a domain that is new for the company through the CIFRE Ph.D. project, as declared in the post-CIFRE company survey ; 0 otherwise.
COMPEQUIP	A dummy variable equal to 1, if the private company looked for accessing to university equipment and experimental know-how, as declared in the post-CIFRE company survey ; 0 otherwise.
Univ. Paris area	A dummy variable equal to 1 if the University facility, in which the Ph.D. Candidate is involved, is located in the Paris Region, as declared by the Parties at the beginning of the Ph. D. project; 0 otherwise.
Univ. exp. with indus.	A dummy variable equal to 1 if the University is used to be involved in joint projects with private third parties, as declared in the post-CIFRE University survey ; 0 otherwise.
Univ. excl. IP	A dummy variable equal to 1 if the University has exclusive IP rights on the outcome of the Ph.D. project, as stipulated in the contractual agreement between the private company and the University; 0 otherwise.
UNIVMASTERED	A dummy variable equal to 1, if the University looked for an experimental field in a scientific domain that is already mastered for the University through the CIFRE Ph.D. project, as declared in the post-CIFRE University survey ; 0 otherwise.
UNIVNEW	A dummy variable equal to 1, if the University looked for an experimental field in a scientific domain that is new for the University through the CIFRE Ph.D. project, as declared in the post-CIFRE University survey ; 0 otherwise.
UNIVEQUIP	A dummy variable equal to 1, if the University looked for having access to the company's equipment on know-how through the CIFRE Ph.D. project, as declared in the post-CIFRE University survey ; 0 otherwise.
Ph.D. Science oriented	A dummy variable equal to 1, if the Ph.D. Candidate is planning to work in academia, as declared in the post-CIFRE Ph.D. Candidate survey ; 0 otherwise.
Ph.D. French nationality	A dummy variable equal to 1, if the Ph.D. Candidate is French, as declared by the Parties to ANRT at the beginning of the Ph. D. project; 0 otherwise.
Ph.D. wage	The Ph.D. Candidate annual income as declared by the Parties to ANRT at the beginning of the Ph. D. project (and in contractual agreement); 0 otherwise.
Ph.D. contractual time with comp.	The Ph.D. Candidate share of the time to be spent in the company's facilities as declared by the Parties to ANRT at the beginning of the Ph. D. project (and in contractual agreement); 0 otherwise.
Ph.D. effective time with comp.	The Ph.D. Candidate share of the time effectively spent in the company's facilities during the CIFRE Ph. D. project, as declared in the post-CIFRE Ph.D. Candidate survey; 0 otherwise.
Ph.D. diverted from research	The Ph.D. Candidate reported that he or she had to perform work not related to the research project for the Company, as declared in the post-CIFRE Ph.D. Candidate survey; 0 otherwise.
Scientific disciplines	A categorical variable depending on the classification made by the ANRT of the scientific discipline of the research project among 10 possible scientific disciplines.
Colab. multi. lab.	More than one University laboratory is involved in the CIFRE project, as declared by the Parties to ANRT at the beginning of the Ph. D. project (and in contractual agreement); 0 otherwise.
Colab. conflict	The Ph.D. Candidate reported conflict between the company's and the university's objectives, as declared in the post-CIFRE Ph.D. Candidate survey; 0 otherwise.
Colab. new	A dummy variable equal to 1, if the private company and the university laboratory are involved in their first collaboration through the CIFRE Ph.D. project; 0 otherwise.
Colab. quarter meetings	A dummy variable equal to 1, if the Parties participated in a joint meeting on the CIFRE Ph.D. project at least each quarter; as declared in the post-CIFRE Ph.D. Candidate survey; 0 otherwise.
Colab. annual meetings	A dummy variable equal to 1, if the Parties participated in a joint meeting on the CIFRE Ph.D. project at least each year and less than each quarter; as declared in the post-CIFRE Ph.D. Candidate survey; 0 otherwise.
Top journal publication	Number of academic publications in top journals of the Ph.D. candidate discipline during the CIFRE Ph.D. project, as declared in the post-CIFRE Ph.D. Candidate survey.
Publication	Number of academic publications of the Ph.D. candidate during the CIFRE Ph.D. project (including those in top journals), as declared in the post-CIFRE Ph.D. Candidate survey.
Patent	Number of patents filled by the Ph.D. candidate with the Company as applicant during the CIFRE Ph.D. project (including those in top journals), as declared in the post-CIFRE Company survey.
Ph.D. Prize	A dummy variable equal to 1, if the Ph.D. candidate was awarded a Ph.D. Prize by a scientific associations, as declared in the post-CIFRE Ph.D. candidate survey.

Table 2 – Summary of variables used.

	Market-pull-oriented Ph.D. (N = 171)	**Research-push-oriented Ph.D.** (N = 384)	**SDI Ph.D.** (N = 80)		
		Mean		**Min**	**Max**
VARIABLES					
Control					
Comp. nbr. employees	34,584.9	28,090.1	26,809.7	0.0	364,795.0
Comp. nbr. Ph.D. employees	39.1	39.0	41.7	0.0	100.0
Cand. wage	28,467.5	28,988.0	29,932.4	23,360.0	57,660.0
Cand. effective time with comp.	0.5	0.4	0.5	0.0	1.0
Cand. contractual time with comp.	0.5	0.4	0.5	0.0	1.0
Dependent					
Nbr. publications	2.3	2.2	2.9	0.0	20.0
Nbr. top journals publications	0.8	0.8	1.3	0.0	9.0
Nbr. patents	0.5	0.2	0.7	0.0	14.0
PERCENT					
Control					
Comp. R&D dpt.	88.3%	82.3%	91.3%	0%	100%
Comp. Start-up	16.4%	9.4%	8.8%	0%	100%
Comp. Paris area	38.0%	44.0%	37.5%	0%	100%
Comp. exclusive IP	18.7%	13.8%	21.3%	0%	100%
Comp. first CIFRE	7.6%	7.0%	21.3%	0%	100%
COMPMASTERED	29.8%	28.1%	28.8%	0%	100%
COMPNEW	59.6%	62.8%	63.8%	0%	100%
COMPEQUIP	10.5%	9.1%	7.5%	0%	100%
Univ. Paris area	22.8%	28.1%	31.3%	0%	100%
Univ. exp. with industry	64.9%	62.0%	56.3%	0%	100%
Univ. exclusive IP	1.8%	0.5%	0.0%	0%	100%
UNIVEQUIP	11.1%	7.8%	11.3%	0%	100%
UNIVMASTERED	28.1%	37.2%	37.5%	0%	100%
UNIVNEW	60.8%	54.9%	51.3%	0%	100%
Cand. Science-oriented	8.8%	16.9%	25.0%	0%	100%
Cand. French nation.	76.0%	79.7%	83.8%	0%	100%
Colab. new	28.7%	29.7%	31.3%	0%	100%
Colab. multi. Lab.	11.7%	15.1%	13.8%	0%	100%
Colab. conflict	36.8%	35.9%	27.5%	0%	100%
Colab. cand. research diverted	54.4%	58.6%	47.5%	0%	100%
Colab. quarter meetings	72.5%	65.6%	65.0%	0%	100%
Colab. annual meetings	97.1%	93.0%	93.8%	0%	100%
Discipline - Mathematics	4.7%	5.2%	10.0%	0%	100%
Discipline - Physics	3.5%	0.8%	2.5%	0%	100%
Discipline - Life Sciences	1.2%	1.0%	1.3%	0%	100%
Discipline - Chemistry	12.9%	16.1%	11.3%	0%	100%
Discipline - Health	5.3%	10.2%	10.0%	0%	100%
Discipline - Human sciences	13.5%	7.6%	12.5%	0%	100%
Discipline - Social sciences	0.6%	10.4%	3.8%	0%	100%
Discipline - Engineering	14.6%	25.5%	8.8%	0%	100%
Discipline - Agronomy	3.5%	4.4%	6.3%	0%	100%
Discipline - TIC	40.4%	18.8%	33.8%	0%	100%
Dependent					
At least 1 publication	72.5%	77.9%	86.3%	0%	100%
At least 1 top journal publication	48.5%	51.6%	63.8%	0%	100%
At least 1 patent	25.7%	11.5%	22.5%	0%	100%
At least 1 patent and 1 publication	19.3%	9.9%	21.3%	0%	100%
At least 1 patent and 1 top journal pub.	12.9%	7.6%	16.3%	0%	100%
Ph.D. Prize	15.2%	12.8%	25.0%	0%	100%

Notes: comp.: company, nbr: number, cand.: Ph.D. candidate, Univ.: University, Dpt.: department, IP: Intellectual Property, multi. lab.: more than one University laboratory involved, TIC: Technology of Information & Communication

Table 3 – Summary statistics

Dependent Variable: At least 1 publication and at least 1 patent				
Model:	(1) Logit	(2) Logit	(3) Logit	(4) Linear
SDI Ph.D.	**1.128**	**1.210**	**1.167**	**0.0269**
	(0.478)	(0.540)	(0.417)	(0.0534)
Research-push-oriented Ph.D.	**0.459*****	**0.528*****	**0.494*****	**-0.0706****
	(0.0687)	(0.0942)	(0.0922)	(0.0252)
Comp. nbr. employees			1.000	0.000000241
			(0.00000283)	(0.000000403)
Comp. R&D dpt.		5.112**	4.057**	0.0828**
		(3.697)	(2.881)	(0.0341)
Comp. Start up		0.327***	0.347***	-0.0695**
		(0.0628)	(0.0728)	(0.0267)
Comp. nbr. Ph.D.			1.001	0.000223
			(0.00297)	(0.000402)
Comp. Paris area			0.570**	-0.0571
			(0.134)	(0.0327)
Comp. excl. IP		1.953**	1.887*	0.101
		(0.635)	(0.662)	(0.0705)
Comp. first CIFRE		0.247**	0.287*	-0.0663
		(0.153)	(0.196)	(0.0418)
COMPMASTERED			1.089	0.0130
			(0.624)	(0.0606)
COMPNEW			0.985	-0.00481
			(0.628)	(0.0648)
Univ. Paris area			1.489	0.0387
			(0.455)	(0.0438)
Univ. exp. with indus.			1.171	0.0196
			(0.391)	(0.0338)
Univ. excl. IP		3.158	3.207	0.116
		(3.361)	(3.033)	(0.142)
UNIVNEW			0.997	-0.00302
			(0.264)	(0.0264)
UNIVMASTERED		1.055	0.974	0.00356
		(0.268)	(0.332)	(0.0358)
Ph.D. Science oriented		0.489*	0.487	-0.0540
		(0.211)	(0.215)	(0.0331)
Ph.D. French nationality			0.562*	-0.0594**
			(0.189)	(0.0263)
Ph.D. wage			1.000	0.00000355
			(0.0000326)	(0.00000332)
Ph.D. contractual time with comp.		2.985	3.241	0.123
		(2.682)	(3.273)	(0.0879)
Ph.D. effective time with comp.		1.624	1.337	0.0397
		(0.915)	(0.771)	(0.0641)
Ph.D. diverted from research		1.103	1.299	0.0293
		(0.300)	(0.447)	(0.0284)
Colab. multi. lab.			1.207	0.0146
			(0.353)	(0.0329)
Colab. conflict			0.798	-0.0236
			(0.191)	(0.0201)
Colab. new			0.548**	-0.0489*
			(0.165)	(0.0256)
Colab. quarter meetings		1.318	1.144	0.0142
		(0.506)	(0.417)	(0.0342)
Colab. annual meetings		0.627	0.457	-0.0442
		(0.383)	(0.296)	(0.0538)
Constant				0.00134
				(0.188)
Observations	635	635	635	635
(Pseudo) R^2	0.025	0.129	0.155	0.115

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

Table 4 – Joint output in CIFRE Ph.D. collaborative projects

Dependent Variable: At least 1 publication, number of journal publications

	(1)	(2)	(3)	(4)	(5)	(6)
Model:	Logit	Logit	Logit	Negative Binomial	Negative Binomial	Negative Binomial
SDI Ph.D.	**2.768*****	**2.378*****	**3.368*****	**1.294***	**1.316****	**1.381****
	(0.842)	(0.771)	(0.982)	(0.178)	(0.160)	(0.182)
Research-push-oriented Ph.D.	**1.644***	**1.333**	**1.807****	**0.970**	**1.014**	**1.013**
	(0.438)	(0.376)	(0.505)	(0.197)	(0.200)	(0.196)
Comp. nbr. employees			1.000**			1.000*
			(0.00000243)			(0.00000046)
Comp. R&D dpt.	1.838		1.788		1.225	1.194
	(0.877)		(0.707)		(0.266)	(0.213)
Comp. Start up	0.775		0.884		0.844	0.910
	(0.250)		(0.343)		(0.128)	(0.153)
Comp. nbr. Ph.D.			1.001			0.999
			(0.00296)			(0.00118)
Comp. Paris area			1.087			1.207
			(0.448)			(0.197)
Comp. excl. IP	1.750		1.661		1.024	0.948
	(0.602)		(0.612)		(0.110)	(0.0979)
Comp. first CIFRE	0.422*		0.491		0.623**	0.671*
	(0.219)		(0.239)		(0.128)	(0.138)
COMPMASTERED			1.433			1.227
			(0.622)			(0.170)
COMPNEW			1.277			1.139
			(0.278)			(0.151)
Univ. Paris area			0.827			0.996
			(0.219)			(0.102)
Univ. exp. with indus.			1.610***			1.261**
			(0.255)			(0.147)
Univ. excl. IP	0.767		0.601		0.532**	0.479**
	(0.664)		(0.564)		(0.142)	(0.142)
UNIVNEW			1.152			0.906
			(0.408)			(0.168)
UNIVMASTERED	0.936		1.019		0.895*	0.798
	(0.268)		(0.248)		(0.0550)	(0.121)
Ph.D. Science oriented	1.094		1.098		1.226**	1.199**
	(0.255)		(0.276)		(0.0994)	(0.0962)
Ph.D. French nationality			0.712			0.781***
			(0.232)			(0.0591)
Ph.D. wage			1.000*			1.000
			(0.0000290)			(0.00000956)
Ph.D. contractual time with comp.	3.320**		3.669***		1.327	1.262
	(1.639)		(1.450)		(0.306)	(0.251)
Ph.D. effective time with comp.	1.194		1.173		1.260	1.213
	(0.481)		(0.528)		(0.178)	(0.178)
Ph.D. diverted from research	0.679**		0.678**		0.981	1.033
	(0.113)		(0.117)		(0.0760)	(0.0882)
Colab. multi. lab.			0.932			0.960
			(0.188)			(0.0832)
Colab. conflict			0.693*			0.829***
			(0.146)			(0.0533)
Colab. new			1.331			0.988
			(0.507)			(0.135)
Colab. quarter meetings	1.636*		1.614**		1.093	1.056
	(0.415)		(0.378)		(0.131)	(0.109)
Colab. annual meetings	1.161		0.964		1.239	1.121
	(0.629)		(0.467)		(0.213)	(0.191)
Observations	635	635	635	635	635	635
(Pseudo) R2	0.071	0.009	0.103	0.003	0.018	0.031

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios, incidence rate ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

Table 5 – Scientific publication output in CIFRE Ph.D. collaborative projects

Dependent Variable: At least 1 patent, number of patents						
	(1)	(2)	(3)	(4)	(5)	(6)
Model:	Logit	Logit	Logit	Negative Binomial	Negative Binomial	Negative Binomial
SDI Ph.D.	**0.838**	**0.994**	**0.977**	**1.555**	**1.773**	**1.736***
	(0.367)	(0.426)	(0.365)	(0.652)	(0.803)	(0.523)
Research-push-oriented Ph.D.	**0.374*****	**0.442*****	**0.426*****	**0.474*****	**0.581*****	**0.541*****
	(0.0588)	(0.0746)	(0.0732)	(0.0671)	(0.0993)	(0.0844)
Comp. nbr. employees			1.000			1.000
			(0.00000305)			(0.00000195)
Comp. R&D dpt.		4.556**	3.443		4.194**	3.233**
		(3.357)	(2.614)		(2.793)	(1.533)
Comp. Start up		0.689	0.759		0.701	0.911
		(0.254)	(0.301)		(0.238)	(0.323)
Comp. nbr. Ph.D.			1.002			1.002
			(0.00271)			(0.00282)
Comp. Paris area			0.632**			0.575***
			(0.113)			(0.115)
Comp. excl. IP		1.831**	1.754**		1.634**	1.499
		(0.482)	(0.495)		(0.347)	(0.397)
Comp. first CIFRE		0.268**	0.323*		0.436	0.587
		(0.147)	(0.206)		(0.238)	(0.314)
COMPMASTERED			0.688			0.490***
			(0.279)			(0.118)
COMPNEW			0.692			0.424**
			(0.324)			(0.175)
Univ. Paris area			1.304			1.233
			(0.337)			(0.310)
Univ. exp. with indus.			1.275			2.012**
			(0.500)			(0.707)
Univ. excl. IP		6.342**	5.661**		3.041**	1.186
		(5.586)	(3.818)		(1.664)	(0.503)
UNIVNEW			0.885			0.876
			(0.271)			(0.263)
UNIVMASTERED		1.005	0.852		0.839	0.689
		(0.239)	(0.280)		(0.204)	(0.190)
Ph.D. Science oriented		0.376**	0.376**		0.437**	0.478**
		(0.160)	(0.159)		(0.171)	(0.139)
Ph.D. French nationality			0.551***			0.605**
			(0.120)			(0.120)
Ph.D. wage			1.000			1.000*
			(0.0000296)			(0.0000370)
Ph.D. contractual time with comp.		1.521	1.543		1.230	1.605
		(1.160)	(1.294)		(0.698)	(1.031)
Ph.D. effective time with comp.		1.692	1.530		3.827**	2.727*
		(1.128)	(1.025)		(2.440)	(1.577)
Ph.D. diverted from research		1.089	1.251		0.996	1.059
		(0.257)	(0.352)		(0.240)	(0.295)
Colab. multi. lab.			0.813			1.089
			(0.264)			(0.394)
Colab. conflict			0.878			0.933
			(0.195)			(0.184)
Colab. new			0.616**			0.690**
			(0.139)			(0.119)
Colab. quarter meetings		1.270	1.099		1.244	1.036
		(0.395)	(0.336)		(0.228)	(0.190)
Colab. annual meetings		0.889	0.733		1.237	1.001
		(0.614)	(0.529)		(0.760)	(0.415)
Observations	635	635	635	635	635	635
(Pseudo) R2	0.033	0.115	0.141	0.019	0.075	0.106

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios, incidence rate ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

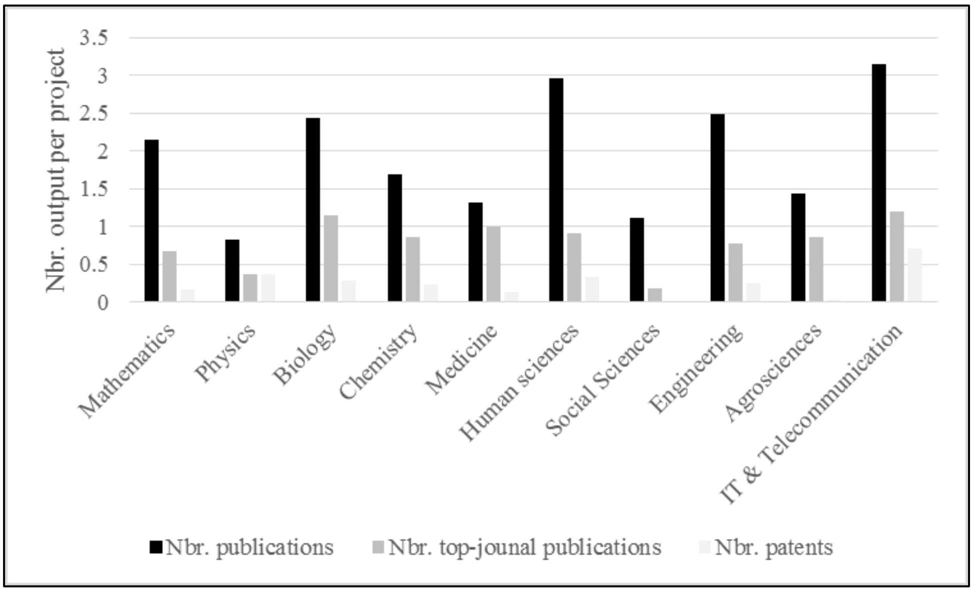
Table 6 – Patent output in CIFRE Ph.D. collaborative projects

8. APPENDIX

	SDI projects average	Non SDI projects average	t-test 99% confidence interval.
Nbr. publications	2.91	2.21	2.42**
Nbr. top journals publications	1.29	0.83	2.67***
Nbr. patents	0.70	0.29	1.70*
Ph.D. Prize	0.25	0.14	2.26**

Legend: * $p<0.1$. ** $p<0.05$. *** $p<0.01$.

Appendix A1 – t-test analysis with unequal variance



Appendix A2 – Output performances per discipline

Dependent Variable: At least 1 top journal publication and at least 1 patent				
	(1)	(2)	(3)	(4)
Model:	Logit	Logit	Logit	Linear
SDI Ph.D.	**1.314**	**1.530**	**1.461**	**0.0434**
	(0.691)	(0.808)	(0.748)	(0.0604)
Research-push-oriented Ph.D.	**0.553*****	**0.652*****	**0.611*****	**-0.0356****
	(0.0875)	(0.0777)	(0.0997)	(0.0127)
Comp. nbr. employees			1.000	-1.69e-08
			(0.00000410)	(0.000000381)
Comp. R&D dpt.		3.456*	2.680	0.0472*
		(2.240)	(1.688)	(0.0237)
Comp. Start up		0.534***	0.515***	-0.0342**
		(0.0783)	(0.121)	(0.0141)
Comp. nbr. Ph.D.			1.001	0.000179
			(0.00354)	(0.000387)
Comp. Paris area			0.458***	-0.0653*
			(0.109)	(0.0321)
Comp. excl. IP		1.580	1.564	0.0568
		(0.453)	(0.545)	(0.0527)
Comp. first CIFRE		0.156***	0.191***	-0.0628*
		(0.105)	(0.120)	(0.0281)
COMPMASTERED			1.103	0.0107
			(0.585)	(0.0451)
COMPNEW			0.850	-0.0164
			(0.529)	(0.0501)
Univ. Paris area			1.856**	0.0517
			(0.506)	(0.0385)
Univ. exp. with indus.			1.333	0.0240
			(0.475)	(0.0264)
Univ. excl. IP		4.903	4.149	0.138
		(5.963)	(4.852)	(0.166)
UNIVNEW			0.810	-0.0183
			(0.256)	(0.0349)
UNIVMASTERED		1.052	0.795	-0.0114
		(0.265)	(0.212)	(0.0269)
Ph.D. Science oriented		0.470	0.457	-0.0472
		(0.219)	(0.226)	(0.0296)
Ph.D. French nationality			0.524**	-0.0576***
			(0.159)	(0.0151)
Ph.D. wage			1.000*	0.00000345*
			(0.0000249)	(0.00000160)
Ph.D. contractual time with comp.		1.882	2.177	0.0585
		(2.106)	(2.645)	(0.0883)
Ph.D. effective time with comp.		1.749	1.430	0.0425
		(1.776)	(1.480)	(0.0918)
Ph.D. diverted from research		1.064	1.247	0.0195
		(0.482)	(0.674)	(0.0364)
Colab. multi. lab.			1.146	0.00751
			(0.209)	(0.0115)
Colab. conflict			0.759	-0.0243
			(0.275)	(0.0261)
Colab. new			0.505**	-0.0464*
			(0.139)	(0.0209)
Colab. quarter meetings		1.456	1.248	0.0161
		(0.552)	(0.491)	(0.0260)
Colab. annual meetings		0.638	0.455	-0.0379
		(0.554)	(0.437)	(0.0582)
Constant				0.0299
				(0.122)
Observations	635	635	635	635
(Pseudo) R^2	0.017	0.091	0.134	0.081

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

Appendix A3 – Joint output with top-journal publications only

Dependent Variable: At least 1 top journal publication, number of top journal publications

	(1)	(2)	(3)	(4)	(5)	(6)
Model:	Logit	Logit	Logit	Negative Binomial	Negative Binomial	Negative Binomial
SDI Ph.D.	**1.865*****	**1.826*****	**1.984*****	**1.643*****	**1.623*****	**1.652*****
	(0.361)	(0.313)	(0.414)	(0.154)	(0.191)	(0.204)
Research-push-oriented Ph.D.	**1.129**	**1.131**	**1.192**	**1.080**	**1.109**	**1.125**
	(0.260)	(0.238)	(0.271)	(0.153)	(0.146)	(0.160)
Comp. nbr. employees			1.000			1.000
			(0.00000118)			(0.00000049)
Comp. R&D dpt.		1.976**	2.158**		1.551*	1.526**
		(0.652)	(0.690)		(0.377)	(0.280)
Comp. Start up		0.660	0.629		0.839	0.851
		(0.272)	(0.300)		(0.186)	(0.192)
Comp. nbr. Ph.D.			0.999			1.000
			(0.00215)			(0.000946)
Comp. Paris area			1.015			1.017
			(0.250)			(0.149)
Comp. excl. IP		1.101	1.065		1.128	1.091
		(0.231)	(0.275)		(0.138)	(0.123)
Comp. first CIFRE		0.522**	0.523***		0.628*	0.674
		(0.151)	(0.125)		(0.167)	(0.176)
COMPMASTERED			1.438**			1.413***
			(0.245)			(0.188)
COMPNEW			1.241***			1.253**
			(0.104)			(0.117)
Univ. Paris area			1.074			1.103
			(0.284)			(0.144)
Univ. exp. with indus.			1.312			1.257**
			(0.225)			(0.134)
Univ. excl. IP		0.682	0.499		0.542*	0.475
		(0.427)	(0.417)		(0.198)	(0.237)
UNIVNEW			0.574***			0.724**
			(0.121)			(0.0991)
UNIVMASTERED		1.162	0.713		0.983	0.741***
		(0.280)	(0.174)		(0.122)	(0.0453)
Ph.D. Science oriented		1.707***	1.649**		1.378***	1.310***
		(0.333)	(0.341)		(0.135)	(0.109)
Ph.D. French nationality			0.678			0.758***
			(0.194)			(0.0680)
Ph.D. wage			1.000			1.000**
			(0.0000245)			(0.00000921)
Ph.D. contractual time with comp.		1.069	1.008		0.986	0.957
		(0.570)	(0.470)		(0.396)	(0.355)
Ph.D. effective time with comp.		1.023	1.098		1.240*	1.259*
		(0.318)	(0.273)		(0.161)	(0.172)
Ph.D. diverted from research		0.841	0.855		0.906	0.949
		(0.196)	(0.206)		(0.118)	(0.110)
Colab. multi. lab.			0.913			0.936
			(0.266)			(0.152)
Colab. conflict			0.717**			0.736***
			(0.100)			(0.0444)
Colab. new			1.094			0.964
			(0.311)			(0.156)
Colab. quarter meetings		1.296*	1.316		1.081	1.062
		(0.186)	(0.248)		(0.111)	(0.149)
Colab. annual meetings		1.497	1.389		1.443	1.309
		(0.732)	(0.719)		(0.407)	(0.365)
Observations	635	635	635	635	635	635
(Pseudo) R2	0.006	0.043	0.064	0.006	0.025	0.044

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios, incidence rate ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

Appendix A4 – Scientific publication in top-journal in CIFRE Ph.D. collaborative projects

Dependent Variable: at least a Ph.D. Prize				
	(1)	(2)	(3)	(4)
Model:	Logit	Logit	Logit	Linear
SDI Ph.D.	**1.859*** **	**1.916*** **	**2.298*** **	**0.107** **
	(0.402)	(0.433)	(0.608)	(0.0413)
Research-push-oriented Ph.D.	**0.816**	**0.774**	**0.811**	**-0.0238**
	(0.192)	(0.191)	(0.206)	(0.0277)
Comp. nbr. employees			1.000**	0.000000687*
			(0.00000245)	(0.000000349)
Comp. R&D dpt.		0.524**	0.455**	-0.0952
		(0.168)	(0.157)	(0.0530)
Comp. Start up		1.085	1.334	0.0428
		(0.508)	(0.617)	(0.0664)
Comp. nbr. Ph.D.			1.004	0.000397
			(0.00365)	(0.000409)
Comp. Paris area			0.714	-0.0378
			(0.160)	(0.0289)
Comp. excl. IP		0.871	0.674	-0.0437
		(0.207)	(0.190)	(0.0342)
Comp. first CIFRE		2.022***	2.653***	0.112***
		(0.458)	(0.492)	(0.0258)
COMPMASTERED			0.487**	-0.0734
			(0.177)	(0.0420)
COMPNEW			0.757	-0.0207
			(0.384)	(0.0582)
Univ. Paris area			2.772**	0.124
			(1.412)	(0.0696)
Univ. exp. with indus.			1.832***	0.0609**
			(0.239)	(0.0190)
Univ. excl. IP		1	1	-0.173*
		(.)	(.)	(0.0942)
UNIVNEW			1.142	0.00876
			(0.338)	(0.0291)
UNIVMASTERED		1.186	1.261	0.0194
		(0.213)	(0.367)	(0.0294)
Ph.D. Science oriented		0.585	0.531*	-0.0586
		(0.240)	(0.196)	(0.0337)
Ph.D. French nationality			0.579***	-0.0622*
			(0.118)	(0.0297)
Ph.D. wage			1.000	-0.00000190
			(0.0000229)	(0.00000275)
Ph.D. contractual time with comp.		0.880	0.916	-0.0126
		(0.546)	(0.519)	(0.0743)
Ph.D. effective time with comp.		0.912	1.072	0.0111
		(0.373)	(0.524)	(0.0602)
Ph.D. diverted from research		1.441	1.668	0.0547
		(0.520)	(0.552)	(0.0408)
Colab. multi. lab.			1.513*	0.0454
			(0.340)	(0.0300)
Colab. conflict			1.029	0.000665
			(0.264)	(0.0294)
Colab. new			1.720*	0.0615
			(0.512)	(0.0365)
Colab. quarter meetings		1.163	1.186	0.0187
		(0.411)	(0.475)	(0.0421)
Colab. annual meetings		1.616	1.809	0.0455
		(0.928)	(1.002)	(0.0571)
Constant				0.159
				(0.106)
Observations	635	630	630	635
Pseudo R2	0.013	0.039	0.101	0.083

Notes: Robust standard errors in parentheses, clustered by discipline. Results are exponentiated coefficients (odds ratios). Base project type is MPO, COMPEQUIP, UNIVEQUIP.
* p<0.1. ** p<0.05. *** p<0.01.

Appendix A5 – CIFRE Ph.D. collaborative projects that received an Award