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**ACADEMIC CULTURE IN DOCTORAL EDUCATION:
ARE COMPANIES MAKING A DIFFERENCE IN THE EXPERIENCES
AND PRACTICES OF DOCTORAL STUDENTS IN PORTUGAL?**

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ABSTRACT

Aim/Purpose	This article examines the experience and practice of doctoral students by focusing on different dimensions of the PhD socialization process. It addresses the question of whether university collaborations with businesses influence the experience and practice of PhD students.
Background	The study explores the academic culture in the PhD process through the analysis of the experiences and practices of doctoral students in two groups – those without business collaborations (academic trajectories) and those with business collaborations (hybrid trajectories). Academic trajectories are seen as traditional academic disciplinary based doctoral education, while hybrid trajectories cross boundaries collaborating with companies in the production of new knowledge.
Methodology	The article uses a qualitative methodology based on extensive interviews and analysis of the curriculum vitae of fourteen Portuguese PhD students in three scientific domains (engineering and technology sciences, exact sciences, and social sciences). The doctoral program profiles were defined according to a survey applied to the directors of all doctoral programs in Portugal.
Contribution	The study contributes to the reflection on the effects of collaboration with companies, in particular on the trajectories and experiences of doctoral students. It contributes to the understanding of the challenges associated with business collaborations.

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Findings	Some differences were found between academic and hybrid trajectories of doctoral students. Traditional products such as scientific articles are the main objective of the PhD student, but scientific productivity is influenced by trajectory and ultimately by career prospects. The business culture influences the trajectories of doctoral students with regard to outputs such as publishing that may act as a barrier to academic culture. PhD students with academic trajectories seem to value international experiences and mobility. Minor differences were found in the choice of topic and type of research activity, revealing that these dimensions are indicative of the scientific domain. Both hybrid and academic students indicate that perceptions of basic and applied research are changing with borders increasingly blurred.
Recommendations for Practitioners	It is important for universities, department chairs, and PhD coordinators to be concerned with the organisation, structure, and success of doctoral programs. Therefore, it is useful to consider the experiences and trajectories of PhD students involved with the business sector and to monitor the relevance and results of such exchange. Key points of contact include identifying academic and business interests, cultures, and practices. A student-centred focus in university-business collaboration also can improve students' well-being in this process.
Recommendations for Researchers	Researchers should consider the processes of interaction and negotiation between academic and business sectors and actors. It is important to understand and analyse the trajectories and experiences of PhD students in doctoral programs and in university-company collaborations, since they are the central actors.
Impact on Society	This analysis is relevant to societies where policy incentives encourage doctoral programs to collaborate with companies. The PhD is an important period of socialization and identity formation for researchers, and in this sense the experiences of students in the context of collaboration with companies should be analyzed, including its implications for the professional identity of researchers and, consequently, for the future of science inside and outside universities.
Future Research	More empirical studies need to explore these processes and relationships, including different national contexts and different scientific fields. Other aspects of the academic and business trajectory should be studied, such as the decision to pursue a PhD or the focus on perceptions about the future career. Another point that deserves to be studied is whether a broader set of experiences increases the recognition and appreciation of the doctoral degree by employers inside and outside the academy.
Keywords	doctoral education, academic culture, university-business collaboration, PhD student's trajectory

INTRODUCTION

European higher education policies, public investments, and guidelines have encouraged a rapid expansion of doctoral education in most European countries. Over the last 20 years Portugal, similar to other countries, has seen a huge increase in student enrollment in PhD programs. The number of PhD enrollments in Portugal surged from 638 in 1998 to 5277 in 2018 and the number of PhD graduates increased dramatically from 375 in 1998 to 2,266 in 2018 (Directorate-General of Statistics in Education and Science - DGEEC, 2019). Doctoral programs and doctoral degrees are increasingly recognized for their strategic importance in the knowledge society (Bin et al., 2016; Jones, 2018). Doctoral education is now seen for its wider benefits to society and requested to respond to needs from different sectors of society, especially from companies (see Van Deynze & Santos, 2020).

Universities in general and doctoral programs in particular are increasingly encouraged to act like firms by capitalizing knowledge and becoming more entrepreneurial by training students for careers outside academia (Thune, 2010). And yet, university-business relations remain tenuous and employment of doctoral holders in companies low (around 6%) (DGEEC, 2015). Recent policy measures have sought to reverse these trends by encouraging intersectoral collaborations between universities and companies and reduce the gap between academic and business cultures. The Ministry of Science and Higher Education introduced specific measures to promote university-company collaboration in doctoral education in an attempt to break down existing barriers and to promote PhD employment. Some doctoral programs were created with companies (“PhD Program with Industry”) and others offer scholarships in companies (“PhD Scholarship with Companies”). In the first case, the programs are financed by the Foundation for Science and Technology (FCT), the public organization that manages funding for science in Portugal, and by industry (with cost sharing of 75 and 25%, respectively). These are often referred to as “industrial doctorate” to highlight the university-industry collaboration and exposure to the dual culture (Carvalho & Cardoso, 2020; Tavares et al., 2020).

Both these programs encourage doctoral students to undertake research activities in companies. The programs have the same duration as traditional programs (four academic years). Some include a course period (usually one year), in addition to the period spent on research, which culminates in the public defence of the thesis (monograph or articles) before a jury (Cardoso et al., 2019).

Universities also promote other forms of collaboration in doctoral education such as internships and work-study programs. Analysis of the doctoral programs based on a survey data to all directors of doctoral programs in Portugal, in 2016-2017, showed that 130 programs (53.3% of the sample) involve some type of collaboration with companies. A substantial part of collaboration between universities and companies in doctoral programmes was connected to the students’ research projects: 52.3% of the students carried out part or all of their research projects with a company and 40% worked on projects defined by the companies (P. Santos et al., 2020).

In summary, new initiatives emerged to support university-business interaction in doctoral education, and yet little is known about the effects of these interactions on the trajectories of the PhD students. This article analyses how university collaborations with businesses influence the trajectories of PhD students. The main research question is what are the main differences between PhD students with and without ties to companies in terms of their doctoral trajectory?

The experience of PhD students with companies, referred to here as hybrid trajectories, is compared to that of PhD students without company involvement. The latter are considered as following a traditional academic trajectory. The comparative focus emphasizes elements that characterize and structure a PhD (see Yazdani & Shokooh, 2018). We will look at (1) the core structure of the research, namely the choice of the topic and the type of investigation, (2) the research process such as the type of activities developed, and (3) the outputs including publications and product results.

Previous studies focus mainly on science and engineering doctorates, we, however, opted to include different fields: these are engineering and technology, exact sciences, and social sciences. These fields were selected to widen the range of possible interactions with businesses as well as the result of a cluster analysis of a questionnaire sent to all doctoral program directors in Portugal. These fields correspond to three profiles of collaboration with companies, described in the methodology.

This analysis includes aspects of academic culture, understood here as a socialization process in which the student learns scientific conventions, including research values and norms (Malfroy, 2005; Merton, 1973). Academic culture finds its roots in Merton’s classic formulation of an ‘ethos of science’ (Merton, 1973).

The trajectories of PhD students are viewed as constructed in a dynamic and plural process of interaction and negotiation with other actors (Mantai, 2017). In university-business collaborations companies become key actors in the socialization process of doctoral students, that is, in the process by

which doctoral students learn and acquire knowledge, culture, rules, and values, as well as the necessary skills to work as researchers (Levinthal & March, 1993). These different pathways and experiences are associated with the “reasonable aspirations” (Bourdieu, 1976/1983) of academic success or integration in the business sector. Thus, the expectation is that PhD students with hybrid trajectories will differ from those with traditional academic trajectories.

The article starts with a review of universities-industry collaborations focused on those in doctoral programs. The second section describes the methodology used to obtain the graduate students’ experience. The third section characterizes the programs and the types of collaboration. The fourth section analyses the students’ perceptions and experiences. The final section presents a discussion of the results, the policy implications, and suggestions for future research.

CULTURES IN UNIVERSITY-BUSINESS COLLABORATIONS IN DOCTORAL EDUCATION

This study contributes to the general reflection on the effects of university collaboration with companies, in particular, its effects on doctoral education. Therefore, the literature reviews the influence of university-business collaborations on academic culture, particularly with regard to doctoral education.

Several studies on collaborative doctoral education highlight the distinction between the business and the academic culture (Campbell & Slaughter, 1999; Y. Lee, 2000; Slaughter et al, 2002). Some identify a confrontation between the two cultures. Slaughter and colleagues (2002) bring to light “cultural” differences in research approaches, the nature and scope of projects, the timelines for producing results, and the identification of problems. The differences accentuate the distortions of research agendas and restriction on the disclosure of results, questioning the norm of open science for research in general. Some studies, as Y. Lee (2000), suggest that universities-companies collaborations involve contracts that often require confidentiality agreements, limiting publication and/or placing restrictions on communication. Campbell and Slaughter (1999) constructed a typology of university-industry interaction conflicts for academics in general. The authors distinguish between conflicts of interest (with public service or funding), commitment (with the academic organization), and equity (academic promotion based on relationships with companies). Boardman and Ponomariov (2009) found that identifying with Merton’s norm of general disinterest prevented researchers from collaborating with companies, indicating the presence of a cultural barrier. The Akay study (2008) found that businesses claim that doctoral holders are overly restrictive and lack professional, organizational, and managerial skills such as teamwork, appreciation of applied problems, and knowledge of other fields.

Other authors find the two cultures are complementary. Harman (2008) notes that doctoral education programs in collaboration with companies integrate academic and business norms, but finds a shift from curiosity-driven research to research oriented to more practical knowledge and technology. Bin et al. (2016) speak of a “cross-pollination” between academia and business and H. Lee et al. (2010) note that pressures on funding in academia have led to greater commercialization with companies, as companies adopt some elements of academia, such as scientific publications.

Other studies indicate that academic-industrial collaborations can have positive effects on researchers’ productivity. Gulbrandsen and Smeby (2005) found that enterprise-funded researchers reported higher levels of publication as well as higher levels of commercial output (including patents) than their peers. Also, Barjak (2006) analyzed academic life sciences research teams and showed that those who published together with co-authors of companies published significantly more articles in total and per member, although their impact was smaller and less recognized in the scientific community.

Some studies indicate that collaborations between the two sectors vary according to scientific domain. For example, the study by Belkhdja and Landry (2007), based on data from 1,554 researchers in the natural sciences and engineering, found that academic researchers are influenced by values promoted by their scientific field - and their recognition mechanisms - which shape their perception and

appreciation of collaboration with companies. These authors also found that companies are less willing to fund projects that are driven by cultural values and research norms opposed to their own. Borrell-Damian (2009) undertook a comparative analysis of 33 doctoral programs with companies in various European countries and found that companies' roles vary according to scientific field. In general, companies tend to be more involved in engineering, technology, biotechnology, medicine, and life sciences; while social science students have limited opportunities to participate in collaborative doctoral programs.

Collaboration can lead to the exchange of ideas that can become a source of innovation and creativity in new and diverse sources of knowledge (Carlsson et al., 2002). Collaboration also has the effect of “connecting” with a broad network of contacts in the scientific and business community (Tijssen, 2018), especially through the hiring of doctoral holders (Slaughter et al., 2002). Approaches that underline the benefits of collaboration from a business perspective indicate increasing the economic relevance of the scientific knowledge produced and the technical skills and access to new technologies and processes (Guerrero et al., 2019; Maietta, 2015). However, at the company level, some studies indicate that the relationship between cooperation with public research organizations and innovation remains ambiguous (Guzzini & Iacobucci, 2017; Pennacchio et al., 2018).

The European University Association study (EUA, 2015) on doctoral education finds that the main benefits in strengthening the interest and involvement of companies in university research is to raise awareness of the technical challenges facing companies, to promote innovation, and to broaden the applicability of results. Overall, university-business collaboration provides an opportunity to change perceptions about forms of cooperation. The same study (EUA, 2015) also identified the challenge of identifying a research project that met both business needs and academic standards with an academic supervisor that understands the objectives and constraints of the business sector and a business supervisor understanding the academic standards of a PhD.

Enders (2005) speaks of “hybrid trajectories” for higher education as a new mode of knowledge production that crosses disciplinary and organizational boundaries, as opposed to the academic-disciplinary model of training. For other authors, there has been a shift from a “traditional doctorate” – with a focus on preparing specialists for a discipline – to a “modern doctorate”, in which knowledge transfer is one of the main objectives (A. Lee, 2018; Muller, 2009). This is the case of professional doctoral programs, defined as the result of a relationship between university, company, and doctoral student (Tiraboschi, 2018). For Jones (2018) the traditional doctoral programs remain largely “mode 1”, while the professional doctoral programs – that ensure greater exposure to other sectors of the economy - is “mode 2”, where research is conducted in an application context.

In summary, studies on university-business interaction provide many examples of advantages, but also of conflicts of interest and cultural distinctiveness. Some of the examples include the commercial influence on the definition of research agendas and restrictions on the publication. The literature review suggests an ambiguous picture of positive and negative effects of university-business collaborations. Some authors emphasized that the benefits and costs of university-industry interaction are undeniable, so the question is how to overcome the barriers that prevent a successful interaction (Bjursell & Engström, 2019; Bruneel et al., 2010). Therefore, further analysis is necessary to understand the effects of the approach to companies in doctoral education.

EFFECTS OF UNIVERSITY-BUSINESS COLLABORATIONS ON THE TRAJECTORY AND EXPERIENCE OF PHD STUDENTS

Studies that look at the effects of collaboration with companies on the trajectories of PhD students are particularly relevant for our analysis. We will present and discuss some of them in this section.

In a synthesis work, Thune (2009) highlights the varying exposure of PhD students that work with companies in terms of the physical environment in which they work, the forms of supervision, the

research projects, and the rules of conduct. The author notes that, based on different studies, compared to non-collaborating students, the effects of collaboration with companies, while positive, are weak in terms of experience and results. The explanation for this “limited impact” has to do with the fact that most studies focus on engineering and life sciences, where university-business collaboration represents a more standardized practice, with greater familiarity of cultures and practices between sectors. Salminen-Karlsson and Wallgren (2008) verified that supervisors facilitate the “translation” of different requirements and generate research projects that are both academically and business relevant. The role of the supervisor assumes key relevance, above all, starting from his/her university-business experience - which tends to be more prevalent in these scientific areas.

Other authors pay more attention to the conflicts and contradictions experienced by students working on business-sponsored projects. Lyon (1995) argues that the dynamics of business collaboration fosters unequal power relations between the different stakeholders. Students, professors, supervisors, and funders need to overcome obstacles so as to enhance independent and academic learning. Blumenthal et al. (1996) also considered students to be particularly affected by industrial confidentiality policies restricting the publication of results. About 88% of companies in the study reported that the agreements required students to keep some data and results confidential. However, Thune’s study (2010) found that in general PhD students were allowed to publish their work after approval of “clean” trade secrets from industrial partners. None of the students experienced delays or impediments in publication. Furthermore, in scientific areas with less tradition of collaboration, such as economics, property rights issues are rarely a concern.

Another set of studies reveals the latitude of PhD students’ experience with collaboration. In the study by De Grande et al. (2014), PhD students who collaborate with companies perceive collaboration as very positive: 83% said they had improved their skills and 81% thought that this contact could open career opportunities outside the academy. Tavares et al. (2020) examine the profiles of industrial doctoral students and, like Thune (2009), find them motivated by employability and career prospects. However, more importantly, industrial doctoral students develop a broader set of skills and competencies to deal with industrial activities of commercialization and application of knowledge. Tavares et al. (2020) also found that doctoral students in Portugal understand the learning process in a double context (academic and business) as positive, especially if it leads to the possibility of employment outside academia. These PhD students are motivated by extrinsic means (labor market opportunities in the period after obtaining the degree), given their field of research to constitute a marketable product.

Some studies seek to understand the outcomes of the collaborations. The outputs of PhD students with and without collaboration also reveal mixed and varied results. Lin and Bozeman (2006) verified the negative impact of the business’s participation on the scientific productivity of PhD students, with influence on later career throughout. In contrast, Salimi et al. (2015) found that project outcomes and impacts were greater for PhD students involved in collaborative projects compared to university-only projects.

The literature review presents different components of the trajectory of PhD students that seem to be important to analyze in an integrated way: purpose (definition of the theme and type of investigation), process (activities developed), and products (type and number of academic results). There is also a lack of an overview of these aspects from the perspective of PhD students. The literature on university-business collaborations involving PhD students is often ambiguous, especially in terms of forms of confidentiality and the possibility of sharing results and scientific outputs.

It is possible to identify important gaps in the literature on this topic. First, as mentioned above, research tends to focus on doctoral education in engineering and life sciences, two fields with the highest degree of interaction with companies, neglecting fields such as the social sciences and humanities. Collaborations with companies in the social sciences and humanities tend to be informal (P. Santos et al., 2020) and, therefore, often ignored by studies that focus on collaborative doctoral programs.

However, we know that, whether formal or informal, students' socialization processes are structured within doctoral programs (Gardner, 2008). Second, in most cases, studies on doctoral education focus on countries with a "developed scientific system" (as referred to by European Commission, 2019) such as USA, Australia, United Kingdom, and Canada (Carvalho & Cardoso, 2020; Jones, 2013). Few studies consider these effects in scientifically less developed countries, which involve differences in resources available for training and opportunities for integration doctorate holders (J. Santos et al., 2016). The Portuguese case can shed a different light on what occurs in a "developing scientific system" where university-company relations are still quite tenuous and employability of doctoral holders in companies is uncharacteristically low. The result of these two factors is limited knowledge about collaborative processes of different natures and in different scientific areas.

The research question on the influence of the collaborative processes with companies on the trajectories of doctoral students remained largely unanswered. The questions of the definition and characterization of the types of university-business collaboration in doctoral programs still needs to be addressed. The different types of collaborations are likely to affect the perceptions and experiences of doctoral students and to influence the academic culture of doctoral programs. That is to say, the business collaboration within academic culture needs to be looked at more closely.

METHODOLOGY AND CHARACTERIZATION OF THE STUDENTS

This study aims to examine the trajectories of doctoral students and to identify the academic experience of students engaged with companies through a qualitative methodology. This approach gives voice to those with first-hand experience. Qualitative research methods also allows a more in-depth analysis of the issues that affected PhD students' experience (see Corbin & Strauss, 2008) and a greater wealth in the description of the trajectories of PhD students, taking into account the specific context of decisions related to the choice of topic, type of research, research activities, and types of outputs. This is also the trend in most studies on doctoral students. Sverdlik and colleagues (2018) found that more than 50% used qualitative methods (for example, interviews, focus groups and case studies).

The methodology is based on extensive interviews with open-ended questions to explore students' perspectives and practices. The structure of the interview script was based on a review of the relevant literature on the topic, but without restricting the PhD students' responses. General evaluative questions such as "how was your PhD?" and "what were the most positive and negative aspects of doing a PhD?" were asked. Other questions attempted to acquire information about the doctoral program and the process of collaboration, such as "how did you decide to do research with/in a company?" and "what does involvement with a company mean to you?"

It is worth mentioning that some studies on the relationship between university and companies in doctoral programs show different views of the different actors involved in the process. For example, Powles (1994), based on interviews with students, academic advisors, and industry advisors, verified the existence of different views regarding confidentiality requirements. Doctoral students assumed the confidentiality restrictions as more difficult than their advisors did. Thus, students' perspectives are relevant.

The interviews took place from December 2018 to February 2019 in the greater Lisbon region. Fourteen PhD students were interviewed from different scientific fields in different PhD programs. Our sample included six interviewees from Engineering and Technology Science (ETS, three female and three male respondents, aged between 28 and 37 years old; four respondents from Exact Science (ES), three female and one male, between 24 and 36 years old; and four respondents from Social Sciences (SS), three male and one female respondents, aged between 30 and 45 years old. The social science students were slightly older with more previous professional experience.

Half of the sample participated in doctoral programs in collaboration with companies and half attended traditional academic programs with no company collaboration. The traditional academic

group with no business collaboration served as a control group (in the same scientific area and region), following the line of a substantial part of the studies on this theme (see Thune, 2009). The collaboration with companies took different forms. Some included research activities within the physical installation of a business including a period of immersion in the business; others involved integrating students from companies into graduate programs. Still others involved a specific doctoral grant with business support or doctoral work undertaken with business data or material. All these possible exchanges or routes of collaboration with companies are referred to as “hybrid trajectories”.

The interviews were recorded, transcribed, coded, and analysed with the MAXQDA program. The analysis used thematic analysis to capture the doctorate’s trajectory (before, during, and after the PhD, in those cases where the student had recently defended his/her thesis), with and without collaboration. The data generated in relation to questions involved an evaluation of the doctoral process at different phases. This led to the construction of nine subthemes that structured the narrative. The different subthemes included the following: 1) PhD motivations, 2) choice of the advisor, 3) thesis topic, 4) research activities, 5) international experiences, 6) type of knowledge produced, 7) skills acquired, 8) outputs and results, and lastly 9) difficulties experienced. This article focused on subthemes 3), 4), 5), 6), 7) 8) and 9), since they contribute more strongly to the empirical exploration of the theme under analysis.

In parallel, the curriculum vitae of 12 of the PhD students were analysed to determine their respective outputs. (Two of the interviewees never sent their CV). Following Lin and Bozeman (2006) we count the numbers of publications in the CVs. In the analysis we took into account the type of academic product (conferences, articles, book chapters), commercial products (patents and products) authorship (authors or co-authors), and scope (national or international) as reported by the interviewees. Lastly, we triangulate this information with the interview data for each student.

CHARACTERIZATION OF THE DOCTORAL PROGRAMS AND THE TYPE OF COLLABORATION

The doctoral program profiles in which the students were enrolled were defined based on a survey applied to the directors of doctoral programs in Portugal, with a response rate of 42.9% (244 cases). The collaboration profiles were defined from a cluster analysis and the three scientific fields of study used in this article fit each of the profiles. The areas within each profile for the analysis described in this article were selected based on the availability of the directors of the doctoral programs to provide contact with PhD students. Below we specify the collaboration profiles of each of the three doctoral fields involved with companies that make up the sample.

The engineering and technology sciences profile is one of continuous and strategic collaboration, and there may be a mix of fundamental research and applied research, as in doctoral scholarships and internship in companies. There is a previous relationship that translates, mainly, into research projects and circulation of doctoral students. There is greater mutual knowledge: the company knows and values the university’s research capabilities; the university understands the company’s procedures, priorities and capabilities. There tends to be active involvement of business partners – at one or several moments – in the scientific work process, such as structuring the research project, guiding doctoral students, or setting objectives to ensure that knowledge translates into creation of new products, technologies, or services. The particularity of a doctoral scholarship in companies, for example, imposes a set of expectations and mutual obligations between the actors involved for the realization of these collaborations. In these cases, business actors redefine the “quality” and “relevance” of the doctoral students’ projects. It is the closest model to the co-creation of knowledge.

The exact sciences profile of the collaboration can be characterized as an episodic collaboration. Despite the fact that companies assume a different role, they mainly maintain an external relationship in relation to scientific production processes. There is a proliferation of collaborative activities but none marked by their intensity.

The social sciences profile of collaboration tends to be a relatively less implicated relationship. It is characterised as involving a material or an instrumental collaboration. It is a more traditional exchange whereby the university shares knowledge and the company shares data and resources to enable or optimize the doctoral research project. The scientific results or outputs of the work will be assessed accordingly.

RESULTS AND DISCUSSION

In the next section, we describe how PhD students reflected on the motive, process, and product of their research. Three main themes emerged with the consolidation of the subthemes defined above. We have identified these categories by their apparent contradictory nature, indicating the process of choice that students must often navigate through in doctoral education. These processes are i) between negotiation and independence of the choice of topic and the research activities; ii) between fundamental and applied knowledge production; and iii) between academic outputs and commercial productivity. Throughout the discussion we integrate quotes that exemplify students' perceptions and attitudes towards these themes. These quotes illustrate the interviewees' prevailing ideas.

BETWEEN THE PROCESSES OF NEGOTIATION AND INDEPENDENCE

The doctoral thesis implies the capacity to define a research topic, determine a research design, and make theoretical and methodological decisions throughout the research process. Roach and Sauer-mann (2010) consider that what distinguishes an academically oriented PhD student from an industrially oriented one is the capacity to determine the research topic.

In our study the PhD students in engineering and technology sciences and in exact sciences, in both trajectories, negotiated the doctoral research topic with different actors. In most cases these negotiations took place with the academic advisors, as expressed in the quote of a female PhD student in exact sciences. Even when a project is previously defined students find some opportunities to negotiate and contribute to the outline of their theses.

The projects were already written and we had to register, apply for the project that ... we were most interested in. ... Within the bases that they gave us, the history of the project, afterwards I had to define a little what was going to happen. Although it is always with the advisor, but for some things I was free to say that I would like to do more. (E1, ES, academic trajectory)

In the hybrid trajectories a further set of negotiations occur with the business partners (especially in the field of ETS). Although academic advisors generally incorporate guidelines a priori, this model can create more tension by reducing or reorienting the student's research topic. The research topic is thus defined through a process of negotiation involving the needs and interests of the university department, the business partner, and the PhD student. The tri-level negotiation process requires the need to balance the various interests. An engineering student describes below the inherent tensions in the negotiation process. The PhD student highlights the added difficulty of adapting a topic of interest to companies to the conceptual and methodological requirements of a doctoral research.

The research problem was provided by the project but it was insufficient; it was cool but not enough for a doctoral thesis. ... For the business it worked, its fine, its perfect; but for me, no. This does not work for a PhD thesis. How do I know what's behind it? And this was difficult for them. I needed to generate data that theoretically was not an added value for the business, but that I needed for the PhD. Later on they came to realize that it was important. But during the initial phase it was quite difficult for them to realize that. (E14, ETS, hybrid trajectory)

In both hybrid and academic trajectories, the negotiation process may imply acceptance of a theme proposed by the supervisor, the project coordinator, or business supervisor and direct it towards the

student's own interests or towards existing opportunities (for example, complementarity with another research project) or future opportunities (for example, a "fashion" sub-theme where funding possibilities are greater). It seems that, in both trajectories, students are prepared to negotiate and direct their efforts towards available opportunities, in so far as their own interests are safeguarded.

The overlap between doctoral research and the supervisor's research is recognized as beneficial for the students interviewed. In the literature this strong interconnection can create a strong field of knowledge and help build a robust research profile for the research unit. PhD students can also acquire access to laboratories, equipment, and other materials, and most importantly ensure professional support (Patrício & Santos, 2019; Pilbeam et al., 2013). But it can also lead to what Ziman (1987) called the "problem of problem choice" – when the topic is defined by other actors and students lose some "distinct value of their products and originality" (Bourdieu, 1976/1983, p. 10), which is an important social capital for these actors and a central value in science (Merton, 1973).

Research activities and practices are also an important aspect in the students' learning trajectories. Students in both trajectories described their main research practices to include laboratory work, data collection, data analysis, communication, and writing. PhD students generally account for these tasks as well as more conceptual tasks, such as theoretical reflection and definition, hypothesis building and planning.

However, the research experience of PhD students in this study varies considerably by scientific domains. There is a heterogeneity of situations between scientific fields and even within the same field (as McAlpine & Mitra, 2015, also found). The students interviewed in the exact sciences conduct research in laboratories, primarily in teams meeting with their supervisor regularly. These students frequently express feelings of being members of a research unit. However, a common feature of this type of laboratory work is the functional division of labour (e.g., Latour & Woolgar, 2013). In our sample the supervisor is frequently responsible for upstream tasks, while students are more involved in the technical tasks such as collecting and analysing data. In social sciences, the PhD students described working alone with infrequent meetings with their supervisors. It is more common for PhD students in social sciences to work on their thesis outside the university. This means that they are far from the research environment and, therefore, experience greater difficulty in building scientific and professional networks (see Calmand, 2016).

In general, students in all scientific fields and in both trajectories value autonomy and express independence as something desirable, considering the passage from student to researcher or, as Dalton et al. (1977) refer to, the transition from "apprentices" to "colleagues". The following quote from a male student in ETS illustrates the idea that freedom is necessary condition for the development of a researcher:

[The supervisors] gave me a lot of space, I think that's very important. I do not know if I would like to have a supervisor on my back every week asking what I did. Because I can't do much in a week, that is, I can and not get anywhere, have nothing to show, and in the following week I will soon have material for the two or three papers during the year. But I feel that I have gained a lot in having people ... who gave me a lot of freedom. (E6, ETS, academic trajectory)

The publication patterns of students reflect the importance of navigating between the patterns of autonomy and collaboration. In the social sciences, single authorship is more common (21.5% of all publications and communications indicated in the CVs). This may be associated with their ability to conduct more autonomous research (Laudel & Gläser, 2008). In engineering and technology sciences and in exact sciences, publication through joint authorship is the common practice (only 11.5% of ES products and 19.3% of ETS products are single authored). In these cases, the PhD students seem to rely on their supervisors and their publishing experience.

The type of trajectory of the PhD students in this study does not predetermine the capacity to negotiate the research topic and to explore autonomous research paths. Doctoral education should provide a path to scientific autonomy (Laudel & Gläser, 2008; Shibayama, 2019), but it is obtained in different quantities throughout the trajectories of these PhD students. The freedom and autonomy to investigate, contrary to what might be expected, is not determined by the type of trajectory or by the pressure of business actors. This autonomy seems to be more conditioned by disciplinary traditions. The overall research experience occurs in a context of multiple influences within academic traditions largely consequential of the scientific field.

BETWEEN FUNDAMENTAL AND APPLIED KNOWLEDGE PRODUCTION

All the students in the study expressed a high degree of recognition and appreciation for “applied knowledge”. This occurred regardless of scientific field or business collaboration. Although the boundaries between basic and applied science are often unclear or blurred, applied knowledge was generally referred by respondents as a more short-term or immediate response to a particular problem and can imply a practical intervention. The quote below from a student in SS and a student in ETS, with and without collaboration with companies, illustrated the relevance of research to a practical result or output and the gratification they feel when the results of their investigation are used by different types of organizations or actors.

I always prefer a little more applied. A scientific question of course, but that has some practical application that result of my work some knowledge that is practical. It's in logic that there are these results, based on these results, new knowledge is produced that can be useful for someone, even if it's for public bodies, for the university, for other researchers. It can be results, methodologies, but knowledge has some practical component, so it's not too theoretical. (E3, SS, academic trajectory)

It is so good to do science as a practical thing, that is, you see a product grow, you see a product that you created, with the help of the team, but you created and that is being used. It's gratifying. I think it's more rewarding than, say, science is now too oriented to 'let's publish'; the goal is to publish. It is often forgotten a bit of the importance of what one is doing. ... You're ... helping the company, you're seeing something created and that's rewarding. ... For a person who wants only to do science is probably limiting, but if you want to combine science with a practical objective it is perfect. (E12, ETS, hybrid trajectory)

For students with hybrid trajectories solving a practical problem meant an extension in the range of their research. The focus on solving problems in real-time situations is seen as having a positive impact on the quality of their projects and on the type of knowledge produced. The experience of working in a company, in a business environment, was in itself a learning opportunity. Developing research within a business environment meant adapting to short-term results, often thinking commercially in an applied context (as observed by De Grande et al., 2014). It also implied developing more technical and business-specific knowledge. They also perceived this as a way to aid future employment prospects, with skills and work experience valued by employers. The PhD students' quotes below help to illustrate the gains in terms of increasing the quality of research in terms of data collected, working methods, well-defined objectives, and acquisition of industrial experience and knowledge, with repercussions on employability outside academia:

For me it was great, because it gave me the opportunity to have data and information, to have goals. ... These projects forced me to have deadlines and to be really focused, something that when a person has a scholarship, and in my case I had a lot of freedom, sometimes you can lose your thread a little. ... Probably, if I had not had the opportunity to work with companies, perhaps my PhD would not have been so efficient. (E11, SS, hybrid trajectory)

Over these five years, in addition to doing my PhD, I gained a lot of experience and a lot of background in the industrial area. ... A doctorate in business gives you that advantage, because when you go looking for something, you will already look for it with an industrial background. You won't be wasting time training someone if you have someone with a PhD there who already knows how it works. (E4, ECT, hybrid trajectory)

We also find that students in both academic and in hybrid trajectories recognize the use, value and importance of science contributing to society; both assume the multiple purposes of research from fundamental to applied. The main difference is that the students with hybrid trajectories have experienced the context and constraints of a business. Students with hybrid trajectories view the collaboration with companies as an additional opportunity provided to an academic trajectory; a contact with the "real world". In practical terms, this means that they have a better understanding of business culture. The quote below illustrates the corporate culture more related to the emphasis on short-term results and less opportunity for exploration:

They have some difficulty in realizing that maybe there are things that do not have great applicability or knowing at the outset that they may be useless, let alone to prove that it is not there. We have to explore. Therefore, explaining that I had to make molecules in order to be able to bridge the gap with my PhD was thus my biggest challenge. (E13, ES, hybrid trajectory).

Integration in companies was not always easy, in particular, adapting to the business culture of hierarchy, priorities and timings. Business and academic culture differ in values and interests and PhD students recognized this. Many students considered dealing with the business culture as an obstacle to be overcome. Some even considered that their role in the company was seen in a negative light, due to a lack of understanding of the importance of academic research and a PhD degree. This is the case of an ES doctoral student that found it necessary to assert her contribution and value to the company.

Integration was not the easiest, because ... there is still a lot of the stigma associated with the doctorate and research that is done in the academy, 'this has no interest'. ... And they did not value my experience either. (E8, ES, hybrid trajectory)

Students in both academic and hybrid trajectories identified the added value of increased specialization, the knowledge-production approach, and the relevance of acquiring "scientific maturity". Scientific maturity is composed, according to the interviewees, of autonomy, independence, and ability to solve problems. For the PhD students these skills and competencies are relevant academic skills suitable for a variety of employment sectors. The skills acquired can be part of professional practice, regardless of the sector of work. In essence, they refer to the transferability of their capabilities and skills beyond the PhD.

The scientific maturity that is gained by the doctoral degree is most important and I think that is what a company seeks, the ability to solve problems, the ability to put ideas into practice, to have ideas. This is something that is very developed in us. ... I think scientific maturity has been building for a long time; it's not something a person learns to do a job here, a job there. ... I think it's a very important competency that I acquired during my PhD and I do not think I had it before that. (E13, ES, hybrid trajectory)

In sum, the distinction between basic and applied research have been recognized as important for PhD students but its significance is clearly changing (as Henkel pointed out in 2004). Students with academic trajectories and students with hybrid trajectories value basic and applied research and consider that knowledge production can be both basic and applied. But students recognize a gap between the knowledge produced in the "real world" and knowledge produced in the "academic world". Those with academic trajectories expect, above all, that their research to have meaning for peers, while those with hybrid trajectories expect to produce practical results. Also, while the

differences between basic and applied research are often fuzzy, the practical side of company integration is seen as an added value in terms of experience and know-how. Sometimes the experience of working in or with a company implies overcoming obstacles and barriers imposed by the different cultures.

BETWEEN ACADEMIC OUTPUTS AND COMMERCIAL PRODUCTIVITY

The differences between academic and business cultures are most revealing in the outputs or results of the research. Both academic and hybrid trajectories value academic outputs, but the type of productivity can vary significantly.

All PhD students consider academic outputs – understood here as scientific publications and participation in scientific events – as an important component of the doctorate. However, the analysis of the CVs reveals differences between academic and hybrid trajectories. PhD students with hybrid trajectories present a wider range of scientific outputs than the students with academic trajectories. Students with hybrid trajectories reveal more involvement in different types of national and international conferences and in commercial results such as registering patents and producing new products or services. Students with an academic trajectory reveal a more focused path concentrating on scientific articles in international well-ranked journals. In other words, pressure for scientific publications in the pursuit of an academic career leads to more instrumental productivity (Henkel, 2000), making PhD students less inclined to engage in devalued outputs such as conferences and articles in national journals. In constructing their space in the scientific field (Bourdieu, 1976/1983) students with an academic trajectory expect their academic performance, in the form of international scientific publications, to positively influence career advancement. This is illustrated in the discourse of a student in social sciences with an academic trajectory:

Nowadays I go less and less to conferences, I go to the ones that really interest me. Now I'm not going to any conference just to go, even if it's in Lisbon. It's not an extra line in the curriculum that will do better, it's a waste of time. (E5, SS, academic trajectory)

In general, students attribute great significance to these events and value publications. The social and professional function of conferences and congresses provide an opportunity to network, to engage, and to feel part of the scientific community. Students thus attribute a meaning of validation, visibility, and peer recognition to these moments, but also point to their potential to develop networking and career opportunities.

By publishing scientific articles students are exposed to scientific dynamics, develop relevant skills, and contribute to knowledge production. However, this issue is associated with the intense pressure to publish, the 'publish or perish' syndrome effecting academia in general, and not only senior academics and researchers (Jones, 2013). The publication becomes a "convertible currency" (Abbott 2019) in job security, finance, higher salaries, and career success (Laurance et al., 2013; Merton, 1973). A student in exact sciences, without collaboration, expressed this. However, it is important to note that the number of post-doctorates in Portugal has been increasing, making these career goals even more difficult to achieve in academia, giving rise to increasingly unpredictable careers (J. Santos et al., 2016).

The motto of my advisor is 'publish or perish', it has to be. Because otherwise, this is a very ... harsh competition nowadays. ... We have to publish more, more, and more to be competitive. (E6, ETS, academic trajectory)

Scientific publications – articles and chapters – are essential achievements for doctoral students in this study while product development is considered less relevant for those who want to continue in academia after the graduation. The CV analysis revealed the publication track of the students, evidencing that a doctoral degree involves more than writing a thesis, it involves writing scientific articles, book chapters, often co-authored with supervisors.

Academic culture also contains an important international component. Students expressed the widely accepted idea that mobility is a prerequisite for successful academic careers, as well as important to obtain some international experience along the way. But the type of experience varied. The students with academic trajectories were more involved in international internships or summer schools. While the most common form of international experience for students with hybrid trajectories was in conferences and seminars, also due to the lower possibility of reconciling with collaboration or integration in the company. That is, the additional experience of PhD students with academic trajectories seems to involve more international collaboration and integration in scientific networks, while PhD students with hybrid trajectories are more involved in tasks and activities with the companies. This is not to say that students collaborating with companies are not international but that the cross-border mobility is usually embedded in company interests. These differences are illustrated in the two following quotes:

During the doctorate they gave us funding for three months to a year to do internships abroad. And I took advantage of the challenge. Because there were collaborations, because I knew people outside, there were collaborations between the laboratory and other laboratories. (E7, ES, academic trajectory)

Usually when you do your PhD...you can have a period abroad. When you are doing a PhD in a company, forget it. It is very difficult for you to succeed. ... It happened because I went to develop work for my doctorate, but I took the company's work to develop as well. (E4, ETS, hybrid trajectory)

Students in academic and in hybrid trajectories were concerned with acquiring international experience as it is highly valued and considered to facilitate access to wider scientific networks. These experiences can result in collaborations with international teams and access to different scientific environments, which is relevant in an increasingly international and interdisciplinary research context. In addition, they considered working outside the university to acquire useful knowledge to advance their research, as they are exposed to different disciplines and to different methodological perspectives. This is reinforced in studies that indicate that international experiences can increase the technical, scientific, and social capital of PhD students, as well as their international recognition (Patrício & Santos, 2019; Recotillet, 2007).

I learned a lot, it was brutally productive from a professional and personal point of view. ... It has been months ... brutal, brutal experiences that I recommend it to everyone who goes for a doctorate, because I learned, I learned immensely during the times I was there. ... In fact, I ended up doing things that I was not expecting to do. ... I incorporated a series of case studies in my thesis because of this. (E5, SS, academic trajectory)

Students in both trajectories are aware of the need to expand the range of experiences beyond traditional academic learning and training. Thus, activities that promote additional skills and extend their networks are sought. Students actively seek experiences that will have important repercussions and strategic advantages (see also Jazvac-Martek et al., 2011; McAlpine, 2012). These parallel experiences are means for them to acquire technical, scientific, and cultural capital, regardless of involvement in collaborative processes with companies.

The interests that distinguish academic and business culture are different and recognized as such by the students. This has repercussions in the process and development of the PhD. The differences are predominantly evident in the outputs that are valued by the academy and by businesses. Students with an academic background considered it necessary to guarantee their involvement in a wide range of academic experiences, including international ones, and achievements more valued in academia, such as scientific articles published in international journals. As Acker & Haque (2017) define, they intend to try to build "academic capital" to have a greater possibility of integration in this field.

CONCLUSIONS

This article has examined the experiences and practices of PhD students in two groups – those with business collaborations and those without business collaborations. Academic trajectories are seen as traditional academic disciplinary based doctoral education, while hybrid trajectories experience cross-organizational boundaries collaborating with companies in the production of new knowledge. This study concludes that the formal differences between an academic trajectory and a hybrid trajectory are minor. The academic culture and its values dominate in a context of tenuous links between universities and companies in doctoral programs. However, there are some differences worth noting.

The greatest difference lies in the types of scientific outputs. Traditional outputs such as scientific articles are the main objective of the PhD student, but scientific productivity is influenced by career prospects (in the same direction as the results of Mangematin 2000). In the case of academic trajectories, students can be guided by “succession strategies” to ensure “the profits promised to those who realize the official ideal of scientific excellence” (Bourdieu, 1976/1983, pp. 17-18). In these cases, the objective is the scientific publication in a well-ranked international journal. Hybrid doctoral trajectories develop paths more directed to the business sector. Students with business experience are able to benefit from the “habitus”, the shared understandings, perceptions, and orientations that they “internalize” during their doctorate. Such an environment leads to results and products, such as patents, prototypes, licenses, and other company-based outputs.

The types of collaboration with companies varied and vary the experiences of doctoral students. Those in hybrid trajectories experienced the most challenges, especially those with a more intense type of collaboration (such as students in the program of engineering sciences and technology). This path is more difficult to navigate, due to the diversity of cultures that shape the process. Socialization in a business environment, in some cases, leads to less freedom and tight deadlines and, consequently, limits the deepening of the questions to be studied (one of the traditional objectives of the doctoral degree) and the writing of articles (one of the most considered products in scientific culture).

This analysis seeks to understand the doctoral process as constructs that differ by type of trajectory, forms of collaboration, and scientific domains. Academic identity continues to be highly discernible by disciplinary field. The disciplinary tradition has implications that are often simultaneous with the different trajectories. In some cases, the dimensions of analysis - such as the choice of topic and the research design – and the scientific domain can be a more relevant and influential variable than the PhD trajectory.

Universities have become increasingly attentive to market logics, introducing new public management and entrepreneurial practices. This has led some academics to refer to the phenomenon as academic capitalism (Jessop, 2018; Slaughter & Rhoades, 2004). The growing tendency is for universities and the academic culture to become increasingly attached to economic values such as commercialization, commodification, and marketization. While this seems to be the case for higher education institutions in general, academic culture remains the core, the central focus, of doctoral education. The study compares the two trajectories by focusing on the academic culture and the academic process of obtaining a doctoral degree. Academic culture in doctoral education, while adjusting and adapting to external tendencies and forces, remains committed to the production of new knowledge and the transmission and diffusion of knowledge while accepting and encouraging diversified channels and circuits. Doctoral programs conserve academic culture as the dominant form.

This study contributes to the understanding of the influence of collaborations with companies on the trajectory of doctoral students, but it is possible to identify four main limitations. First, not all scientific fields were included. While we included fields that are not normally discussed in the literature on universities-business collaborations in doctoral education, other scientific areas, and their cultures were left out. Second, a limited number of doctoral students were interviewed. Third this study was

carried out within a specific national context, limiting generalization. Although the study was located in Portugal, the stories resonate with the tendency reported in other European countries (De Grande et al., 2014, Van Deynze & Santos, 2020). More comparative studies with countries similar to Portugal that reveal a diversity of programs and high rates of growth to qualify human resources may be appropriate. Finally, we must recognize that this study analysed only some of the components of the doctoral trajectory. Other aspects of the trajectory, such as the influence of the PhD trajectory in the future career, can offer interesting questions for further research.

Continuing to capture the representations of the experiences of doctoral students in the context of collaborations with companies is important since they are the central actors in both processes – doctoral program and university-company collaboration. The study provides important information for universities to monitor these processes and their influence on the path of new researchers. These results, complemented by other studies, may allow for more thoughtful decisions on the part of students when opting for a PhD in collaboration with companies. The study indicates that such university-company collaborations can be planned with care so that the scope of the research is not limited or side-tracked.

Research activities are an integral part of the trajectories of the doctoral students and are not hindered or diverged by collaborative processes with companies in the fields studied. Academic outputs, however, seem to be more influenced, in particular when related to expectations and perceptions concerning implications on the students' professional future. This leads to another point that deserves to be studied. Can a broader set of experiences and perspectives in the trajectories of doctoral students increase the recognition and appreciation of the doctoral degree by employers outside the academy? The answer to this question addresses one of the primary purposes of the introduction of the measure by the government to promote collaboration.

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