Building bridges between industry and academia: What is the profile of an industrial doctorate student?

Orlanda Tavares, Cristina Sin, Diana Soares

Introduction

The knowledge society and economy has implied transformations in the relationship between governments, universities and industry, the three pillars representing the triple helix[1] driving innovation in the contemporary world, as theorised by Etzkowitz and Leydesdorff (2000). This relationship raises implications for the relevance of higher education to the outside world, requiring institutions to follow closely the tendencies beyond its walls. Higher education is increasingly viewed as instrumental in the contribution it can make both to society and to economy (Slaughter & Rhoades, 2004). This resulted in a broadening of its missions to include, beyond teaching and research, the 'third mission'. The third mission presupposes that the produced knowledge contributes to social and economic development (Pinheiro, Langa & Pausits, 2015) and one of the consequences has been the reorganisation of the operations of the university as an 'entrepreneurial university' (Clark, 1998) in many institutions in developed countries (Ashraf et al., 2018).

Higher education is called upon to respond to nowadays social, cultural and economic challenges, which requires opening up and paying more attention to the interests of employers, the demands of policy-makers and the needs of students. To meet these expectations, higher value has been attributed to knowledge with potential for application in the real world, triggering a shift in knowledge production from Mode 1 to Mode 2 knowledge (Gibbons et al., 1994) and even, very recently, to Mode 3 knowledge (Carayannis, Campbell & Rehman, 2016). Mode 2 knowledge often entails transdisciplinarity and collaborations among diverse actors (Bienkowska & Klofsten, 2012). The changes in knowledge production have had implications for the research activities carried out in higher education institutions and, consequently, for research training. This has become evident in the criticisms often addressed to doctoral education for not being relevant outside academia, where relevance is understood as preparing doctoral students capable of working in other sectors of society and industry (Roberts, 2018; Kyvik & Olsen, 2012; De Grande et al., 2014). De Grande et al. (2014) also argue for a mind-set change among doctoral researchers and supervisors in order to turn them more receptive to employment outside academia.

In this context, a new type of doctoral degrees has emerged which involves the collaboration with industry, often designated in the literature as industrial or collaborative doctorates (Borrell-Damian et al., 2010; see Kehm's chapter in this book for a typology of doctoral programmes). According to a report by the European University Association (EUA), collaborative doctorates imply that doctoral theses are 'carried out with interaction between a university, a company and a doctoral candidate. A distinctive characteristic is that industry experts take part in the

supervisory committee, officially or informally. Industry can play several roles, but being in the supervisory committee is what effectively reflects the specific nature of the collaborative doctoral project' (Borrell-Damian, Morais & Smith, 2015). In several European countries governments have set up policy schemes to support collaborations in doctoral training by committing resources through public funding programmes (European Commission, 2011).

Industrial doctorates aim to ensure broader career prospects and the diversification of labour market outcomes for doctorate holders, since the capacity of academia to absorb growing numbers of doctorate graduates is limited (Roberts, 2018; Wardenaar et al., 2014; Thune, 2010). This kind of doctoral education is a reflection of the triple helix model as it emphasises an entrepreneurial mind-set and competencies needed for knowledge commercialization, exposure to 'real life problems' and collaboration with industry or government during the development of doctorate programmes (Thune, 2010). Collaborative doctoral programmes expose students to both academia and industry. According to Kihlander et al. (2011), being an industrial doctorate student means that the research is closely linked to the company, but the student is also affiliated to a research department at a university, hence he/she is exposed to a dual culture. Despite the benefits of this exposure, some authors are critical of the limitations to academic freedom and autonomy and the implications for the progress of science (Henkel, 2017; Santiago, Carvalho & Ferreira, 2015).

Doctoral students are significant producers of knowledge in collaborative research projects, important channels for knowledge transfer and vital in network configurations between firms and universities (Thune, 2009). It is therefore worth understanding what kind of characteristics are needed for a student to be able to fulfil these roles as bridge builders (Borell-Damian et al., 2010), not only as students, but also after graduation. Some of those characteristics put forward in the literature include transdisciplinary competencies and 'team science' skills and attitudes (Nash, 2008), the ability of integrating knowledge from different disciplines and sectors to find or improve existing solutions and transferable skills (such as communication, leadership, ability and willingness to change, creativity, etc.) (Borell- Damian et al., 2010).

This chapter studies the perceptions of students enrolled in Portuguese industrial doctorates about what sets them apart from other doctoral students. Analysing this topic through the lens of students' perceptions contributes to knowledge on the profile of the industrial doctorate student – what motivates them, who they are and who they become. Starting from the premise that students in industrial doctorates act as bridge builders between industry and academia, the aim of this chapter is to analyse whether students' profile reflects the dual culture. The effectiveness of the bridge is partly dependent on students' assimilation of the hybrid nature which research training in an industry context entails. Drawing on focus groups discussions, the following aspects are analysed: motivations and expectations behind their enrolment, the personality traits perceived to be in tune with the demands of industrial doctorates and the skills and competences acquired

during the programme. Although the importance of doctoral students in university-industry relationships is acknowledged in the literature, research focusing on students themselves is limited (Thune, 2010). For example, gaps are identified in relation to expectations, motivations and acquired competences (Roberts, 2018; Thune, 2010). The lack of studies is even more evident in Portugal, where industrial doctorates are quite recent (Santos, 2017).

The European and Portuguese context of industrial doctorates

In Europe, universities have been intensifying research collaboration with industry, including at the level of daily exchange of knowledge with firms, involving scholars and students (e.g. spinout companies, science parks, incubator units) (Borrel-Damian et al., 2010). The estimates point to the fact that more than half of doctoral candidates find employment outside academia. This has encouraged the establishment of industrial doctorates, which are funded by industry or government programmes that involve industrial participation. The financial contribution of industry varies between 25% and 80% of the costs (Borrel-Damian, Morais and Smith, 2015). France, Denmark, the UK, Italy, Finland, Sweden or Estonia have promoted such collaboration through government-led schemes (Borrel- Damian et al., 2010; Cardoso, Tavares and Sin, 2019). Such collaborations in doctoral programmes do not emerge only as top-down initiatives stimulated by the government, but also as bottom-up endeavours of institutions or companies. However, it is recognised that public support is essential, consisting not necessarily of funding only, but also of adequate policies and legislation to foster university-business partnerships in doctoral education (Borrel- Damian et al., 2010). Geographical proximity between companies and universities is a key factor which facilitates the development of collaborative doctorates (Borrel-Damian, Morais and Smith, 2015). There are differences in the legal status of candidates in industrial doctorates: employed part- or full-time by the company, employed by the university or candidates funded by scholarships from a public research body (Borrel-Damian, Morais and Smith, 2015).

The Portuguese context of industrial doctorates is characterised by a high level of public support and encouraged by a top-down government-led scheme. This, in fact, applies to all doctoral education in Portugal, which, until the mid-1980s, was very scarce in Portugal. At the time of the 1974 democratic revolution, Portuguese higher education institutions awarded a very limited number of doctoral degrees because of the elitist nature of the higher education system. The majority of PhD holders had the degree awarded abroad. Once Portuguese institutions developed capacity to train PhD students, public policies started to foster the advanced training of human resources in the country, by means of scholarships (Heitor et al., 2014). The fast expansion of higher education following the revolution was also reflected in the increasing number of awarded PhDs (from 292 in the 70s to 3823 in the 90s). The number of PhDs awarded after 2000 was 35 times higher than the number of those awarded in the 1970s, and more than eight times the number of those awarded in the 1980s (Tavares et al., 2015). This expansion occurred partly because of

new legislation in 2006 which stipulated the percentages of PhD holders among academics teaching in the different higher education qualifications (first degree, master and PhD) and also in 2009 which made the PhD a pre-condition for entry into a permanent academic career. Before 2009, the PhD was only necessary for career progression and academics could enter the academic profession without this qualification (Carvalho, 2012).

In Portugal, doctoral degrees can only be awarded in universities, 24 in all, out of which 14 are public and 10 are private[2]. The majority of doctoral programmes are traditional research doctorates. A doctoral candidate has a student status and pays doctoral tuition fees, except when scholarships are granted. The main funding body is the Foundation for Science and Technology (FCT), which supports doctoral education through two funding strands: doctoral programmes and individual doctoral scholarships. The doctoral programmes can be national, industrial and international (FCT, 2018).

So far, 96 doctoral programmes have been funded in a competitive scheme and seven of these are industrial doctoral programmes (FCT, 2018). However, according to the Portuguese accreditation agency database, only six are in operation. These six industrial doctorates are offered in universities located in urban areas with dynamic economic activity, which reinforces the importance of geographic proximity between universities and companies. Industrial doctoral programmes are funded both by the Foundation and by industry (respectively 75% and 25%) and aim to foster the development of research activities in a business environment. The responsibility for these doctoral programmes is jointly shared by at least one university or a Portuguese university institute, a Portuguese R&D unit recognised by the FCT and a company with significant R&D activity (FCT, 2018). Industrial doctorates have the same duration as research doctorates (three or four academic years). Supervision can be conducted jointly between an academic supervisor(s) and an industry representative. This collaboration requires compromise because of the different objectives underlying their engagement with knowledge. When academic knowledge assumes a great importance, industry supervisors seem to accept a minor role in supervision (Salminen-Karlsson & Wallgren, 2008). However, collaboration with industry can happen in other aspects such as: the selection of doctoral candidates, the choice of research topics, curriculum development and teaching, and assessment of doctoral work and thesis (Cardoso, Tavares & Sin, 2019).

One of the motivations driving the creation of industrial doctorates is related to extending graduates' employability in sectors beyond the academia and supporting innovation in the industry. In Portugal, the private sector is made up mainly of small and medium companies, which attach low importance to human capital and innovation and, as a result, the demand for highly qualified resources is limited. Thus, Portugal is one of the OECD countries with the highest proportions of doctorate holders working in the higher education sector (83.2%) and a lower presence in the private industry sector (Santos, 2017).

Profile of the industrial doctorate students

Contemporary doctoral students are far more different from the traditional ones, as they are more in number, more diversified, have different starting conditions, motivations or expectations. Doctoral students no longer have the traditional and delimited profile, which corresponded to a student studying full time, on campus and pursuing an academic career. Nowadays, it is possible to find a rich diversity of student profiles, either full or part-time, both on campus and at a distance, single or married, with or without children (Offerman, 2011), pursuing academic and other sector careers. Additionally, doctoral students are under higher pressure to develop a broader range of skills that will enhance their marketability to a variety of users on graduation (Wardenaar et al., 2014).

Doctoral education also had to readjust to these variety of profiles in order to respond to their different ambitions and expectations. A new emphasis on the integration of the graduate experience with outside work combined with a move away from the more traditional disciplinary-based research training model in the sciences gave rise to industrial doctorates (Harman, 2004). Industrial doctorates tend to attract a different type of doctoral students, preferentially those who are able to adapt to the broader goals of the programme and are open to different types of collaborations, who are proactive and open-minded (Briscoe et al., 2006; Seibert et al., 1999). Industrial doctorates are more likely to develop dissemination and translation skills (boundaryless mind-set, multidisciplinary approach, stakeholder involvement, society-oriented outlook) and transferable skills (Wardennar et al., 2014).

Drivers and motivations

Students enrol in doctoral programmes for several reasons and are driven by different motivations, which are often generally classified in the literature as intrinsic and extrinsic. While intrinsically motivated students choose an activity for its own sake, for the enjoyment it provides, the learning it allows, or the feelings of accomplishment it evokes, extrinsically-motivated students try to obtain some reward that is external to the activity itself, such as grades, social approval, parents' expectations or employability (Lepper, 1988; Tavares & Ferreira, 2012). According to Celis and Duque (2016), intrinsically motivated doctoral students tend to have a preference for science, for basic and purely academic research undertaken in traditional research doctorates, whereas extrinsically-motivated doctoral students tend to have a preference for commercialisation and for applied research capable of producing innovation in an industrial context. Therefore, contrary to students who prefer science, whose ambitions are to create, share and disseminate knowledge considered essential for the development of science and the improvement of society, students who are driven by the preference for commercialisation pursue projects targeting the production and commercialisation of innovation-based products. For this reason, these latter are interested in funds availability, resources and cutting-edge technology and equipment (Celis & Duque, 2016).

Hence, extrinsically-motivated students would arguably be more inclined to enrol in an industrial doctorate (Fritsch & Krabel, 2012).

According to Hancock, Hughes and Walsh (2017), doctoral students hold four moral positions towards their acceptance/rejection of the knowledge economy: scientific purists, social idealists, pragmatists and third-order capitalists. While the former two respectively favour academic science and the improvement of society through scientific research, the latter two are prone to see science as instrumental for economic development. Purists and social idealists are interested in an academic career, while pragmatist have flexible career prospects (both in academia or in industry) and third-order capitalists reject academic careers, seeing themselves employed in non-academic labour markets (Hancock, Hughes & Walsh, 2017). Based on these characteristics, it is likely that students in industrial doctorates hold moral positions somewhere between pragmatists and third-order capitalists.

Industrial doctorate students are also driven by employability, career ambitions (preferred employment sector) and career prospects (easiness to find a relevant job) (Thune, 2009; Roberts, 2018). According to Roberts (2018), students of industrial doctoral programmes seek the opportunity to develop and update their skills through professional experience and to gain awareness of multiple employment sectors. While similar career ambitions can be found among doctoral students collaborating with industry and non-collaborating students (Thune, 2009), in what regards career prospects students in collaboration with industry appear more optimistic than non-collaborating students, as the former believe that it will be easier for them to find relevant work after graduation (Thune, 2009). The ability to find employment more easily is ensured by skill development through teamwork environments (Kyvik & Olsen, 2012; Roberts, 2018). With a career in industry in mind, interacting with industry offers students competencies, access to data and research material that are seen as vital for future research careers both inside and outside the university (Thune, 2010).

Therefore, carrying out research in collaborative projects and developing a broader set of skills influences the career trajectories of students in industrial doctorates and has long term impact on career patterns (Manathunga et al., 2012; Thune, 2009, 2010; Wardenaar et al., 2014). Evidence from a literature review (Thune, 2010) suggests that graduates who collaborate with industry during the doctorate have better labour market prospects and are more frequently employed in the private sector than students who do not collaborate with industry. Manathunga et al. (2012) similarly argue that there is a higher tendency for these students to gain employment in industry and in public sector research organisations. A more recent report by the European University Association (Borell-Damian, Morais & Smith, 2015) confirms this trend. A study conducted in 13 European countries found that universities, companies and doctoral candidates all consider that graduates of collaborative doctorates had more job opportunities in the non-academic sector than doctorate holders who graduated from a traditional programme. According to the authors,

the ability to be 'bilingual', bridging the academic and business sectors, and the acquired transferable skills were highlighted as the main reasons accounting for the collaborative doctorate holders' enhanced employment prospects outside academia.

Competences

Thus, one of the aims behind the transformation of doctoral education has been to prepare a new generation of researchers able to embark not only on a career in academia, but who also possess ties to and competencies relevant for other sectors and professions (Borell-Damian et al., 2010). This requires a different set of skills, beyond the academic skills acquired in a traditional doctorate. According to De Grande et al. (2014), employers seem to encounter deficits in transferable skills, such as being able to work with others, and having general management skills such as project management and business skills.

A literature review on doctoral students' experience of the interaction with industry (Thune, 2009) revealed that those students who are involved in collaborative arrangements have a markedly different training experience than non-collaborative students. In turn, this leads to differences in the skills and competences they develop (Lee & Miozzo, 2015; Wardenaar et al., 2014), which, in the case of industrial doctorates tend to be broader and more aligned with industrial activities of commercialisation and application of knowledge. According to Roberts (2018, p.1), this encourages a rethinking of the professional identity of these doctoral students, who 'acquire an interdependent suite of skills from a range of contexts and set goals in multiple working environments', thus being more versatile than their traditional counterparts. For example, Lee, Miozzo, and Laredo (2010) refer to researchers employed in public organisations who see themselves as Project Managers. They also mention the very different business environment characterised by precise end goals and tight deadlines, where teamwork is critical and scientists are simultaneously involved in several projects.

Research literature highlights a number of specific competences among industrial doctorate students/graduates which make them fit for a career outside academia. The research objectives of doctoral students carrying out industrial projects are targeted at solving firm-specific technical problems or developing firm prototypes or specifications. These are also benefiting from the close interaction with industry through meetings and presentations during their doctoral training (Lee & Miozzo, 2015). Thus, they have the opportunity to get familiar with the industrial environment and working practices, which in turn facilitates their transition to a career in industry (Lee & Miozzo, 2015). According to Wardenaar et al. (2014), the involvement of heterogeneous partners enriches students' knowledge and confronts them with a diversity of values, incentives, and practices. This increases their ability to adapt to boundary-crossing research. Roach and Sauermann (2010) additionally emphasise industrial doctorate students' entrepreneurial knowledge and skills, their ability to build connections with the scientific community and

integrate knowledge networks valuable for businesses. Although not at the level of doctoral education, Smith et al. (2008) argue that industry-based learning allows students to understand organisation cultures, work ethic, standards, and expectations of industrial sectors. Similarly, a literature review by Lee (2008) found that industry-based experiential learning facilitates the acquisition of negotiation skills, management and leadership skills, financial management, and the ability to take initiative and to socialise with other professionals.

Comparing doctoral students in collaborative multi-actor projects with students in traditional trajectories in the UK and the Netherlands, Wardenaar et al. (2014) concluded that being involved in multi-actor research projects (MARPs) appears, indeed, to have a positive effect on skills development, resulting in a broader skillset. They found that the academic research skills and academic communication skills of students in MARPs do not suffer as a result of exposure to the hybrid environment; additionally, these students report higher non-academic skills (such as translation and dissemination skills and transferable skills) than students in traditional trajectories. Doctoral students in multi-actor projects also score higher on 'boundaryless mindset', associated with working across organisational boundaries.

Methodology

Participants

Focus groups (FG) were conducted with 30 industrial doctorate students, organised in six groups, having between three and six participants (Table 1). Groups were organised by doctoral programme and each comprised students enrolled in different years, therefore in different stages of their doctoral trajectory. Participants came from the six doctoral programmes in partnership with industry funded by the FCT, as mentioned above. These programmes belong primarily to two disciplinary areas: Engineering (Refining, Petrochemical and Chemical Engineering, Advanced Engineering Systems and Biomedical Engineering) and Health and Medical Sciences (Animal Science, Health Sciences, and Pharmaceutical Sciences). Each group comprised between three and six participants (see Table 1 for additional participant details). Almost all were full-time students (96.7%) and had previous professional experience (70%). In order to apply, students had to meet the competitive criteria established by the FCT for entering doctoral programmes. Additionally, the selection involved interviews by the coordinator in order to assess students' suitability and motivation for this kind of collaborative programme. Admitted students have the same scholarships as other doctoral students who were awarded funding from the FCT to undertake research-based PhDs.

Table 1

Participant characteristics

Participant	*FG 1 (n = 6)*	*FG 2 (n = 4)*	*FG 3 (n = 6)*	*FG 4 (n = 6)*	*FG 5 (n = 3)*	*FG 6 (n = 5)*	*All (n = 30)*

Characteristics							
Gender Male Female	4 2	1 3	3 3	3 3	1 2	3 2	15 (50%) 15 (50%)
Mean age (years) (range)	28 (25-31)	30 (27-34)	29 (26-35)	26 (25 – 38)	29 (27-30)	30 (28- 35)	28,7 (25-38)
Disciplinary area	Engineering (Advanced Engineering Systems)	Health and Medical Sciences (Pharmaceutical Sciences)	Health and Medical Sciences (Animal Science)	Engineering (Biomedical Engineering)	Engineering (Refining, Petrochemical and Chemical Engineering)	Health and Medical Sciences (Health Sciences)	
Full-time student	6	4	5	6	3	5	29 (96.7%)
Previous Professional experience	6	4	4	2	2	3	21 (70%)

All doctorates were attached to companies, which ranged from big international/national firms small and medium enterprises, some of them spin-offs of the research labs of the university. Each programme had at least one major company as a partner. Supervision was shared between university and industry representatives in most cases, with an academic and an industrial supervisor. In two doctoral programmes only, academics supervised the doctoral thesis, while company representatives acted as business coordinators or as 'problem owners', responsible for supporting students in the company.

Procedure

At the beginning of each focus group, written informed consent was obtained. Students were also asked to fill in a sociodemographic questionnaire. After their consent, the focus groups were audio recorded and transcribed. Focus groups were conducted between February and June 2018, and lasted between 45 and 60 minutes. The focus groups were facilitated by two researchers and approached a wide range of topics about students' experiences and challenges, from the moment of application up to the point where they found themselves at the time of the interview. In this chapter, the focus lies on two broad areas: (i) reasons, motivations and expectations of an industrial PhD; and (ii) specific competences (personal attributes and acquired skills).

Data Analysis

A content analysis of each focus group was carried out using the MAXQDA software (version 12). Data were analysed using both a deductive approach, based on the literature review, and through an inductive analysis approach (Braun & Clarke, 2006; Hennink, 2013). Each

transcription was read and coded, line by line, to identify themes that were acknowledged in the literature review as key dimensions of an industrial doctorate student profile. New themes were also added, according to new insights that emerged from the transcripts. Themes were categorised under two key-dimensions of the industrial doctorate student profile: (1) drivers and student motivations; (2) and competences.

Findings and discussion

This section is organised according to the two above-mentioned dimensions that structured the analysis and presents the key findings which allow the definition of the profile of Portuguese doctoral students enrolled in industrial doctorates.

Reasons and expectations for choosing an industrial doctorate

The following reasons and expectations emerged during the discussions: link between industry and academia, applied research and employability and career prospects. First, participants emphasised the *link between industry and academia* as one of the main drivers for choosing an industrial doctorate. Both worlds (academia and industry) could be tied together through this doctorate, offering students the opportunity to develop research within industrial contexts. Theoretical expertise becomes practical and applied to 'real' problems:

> 'I always wanted to do a PhD but I did not want to do one which would stay in the drawer, I wanted something applied, which had an economic context and feasibility. This idea of joining both worlds, industry, which has real needs, and the university, which has the scientific part. (…) So I think it was a good opportunity. This was the main reason.' (FG2).

To develop a doctorate with an industrial applicability was also mentioned by the students as one of their motivations. As stressed by Celis and Duque (2016), this *applied research*, capable of producing innovation within an industrial setting, is considered one goal for students' enrolment in an industrial doctorate. Being more extrinsically-motivated (Fritsch & Krabel, 2012), industrial doctorate students are driven not only by basic and purely academic research development, but also by the ambition of producing and commercialising innovation-based products (Celis & Duque, 2016). The following transcripts are representative of this kind of motivation:

> 'I always wanted to do a doctorate, but I wanted something that was applicable and that has an economic impact (…) my research needs to be an idea with viability.' (FG3).
>
> 'I am a very practical person and I like to see things happen. I like to see people using what I am doing.' (FG6).
>
> 'There is a greater opportunity to achieve something tangible and visible. It is also expected that the company has some output that could be commercialised'. (FG2).

An equally important reason for choosing an industrial doctorate was the perception of greater *employability and career prospects*. Students stated that an industrial doctorate not only offered a degree, but also enabled them to gain work experience in industrial contexts. As corroborated

by Roberts (2018), students of industrial doctoral programmes sought the opportunity to develop and update their skills through professional experience. Hence, interacting with industry offers students competencies that go beyond the specificity of each disciplinary area (Kyvik & Olsen, 2012; Roberts, 2018). Competences such as teamwork, flexibility or interpersonal communication are perceived as key dimensions for their future employability, both inside and outside the university (Thune, 2010).

> 'I enrolled in this PhD because I think it was the only opportunity to work in this area in Portugal. After my 4-year PhD, I can even stay in the company. It was an opportunity to start a career in the field'. (FG1).
>
> 'I think it is a way to have more than a solution for the future, more than just one possibility: to have an academic career or to have an industrial career'. (FG6).

This 'unique' combination of experiences of the dual culture - academia and industry - works as a differentiation factor, benefiting those who already have an involvement in industrial contexts (Thune, 2009). This positive perspective regarding career prospects was invoked by participants, as they believed that it would be easier for them to find a relevant job after graduation.

'It could be an added value: at the end of my PhD I could stand out from the other colleagues who may want to apply for the same position'. (FG5).

Despite being optimistic, students did not put job opportunities in academia and industry at the same level. Some students acknowledged the added value of being familiar with the dual culture, which enabled them to be employable in both those worlds. However, when referring to academia, the prospects were not very appealing, because they did not imagine themselves as professors but as scholarship holders, which is, in Portugal, a precarious status to undertake research. The following transcript is representative of this expectation:

> 'We are a bit more open minded, we can apply for a post-doc scholarship but we can also get a job in a company'. (FG3).

Therefore, students considered that job opportunities would come mainly from industry, where employers would recognise their value.

> 'I think companies will no longer look at us as academics, as those people who have only been in the laboratory and ignore what is done in the company. They will look at us in a different way'. (FG4).

Better career prospects in industry do not necessarily mean that students expect to be employed in the partner company where their research is being developed. Whereas some students developed that expectation, others recognised that as the partner company is a *start-up*, it would be difficult to get employed there. The following two transcripts are illustrative of these two perceptions:

> 'I would like to stay in the company where I am developing the project. The companies that hire us to do these jobs think that we are suitable to work there, because we will

spend 4 years developing a project for that company. They see us as if we were workers. Of course, many of those who enter may not want to stay, may want to go abroad or the company may also say "I provide you with the training, but we won't hire more doctoral students because we are already full". This does not mean that it cannot open the door to another type of company, because companies know each other and therefore we improve our employability.' (FG5).

'I think the problem is that usually *start-ups* are small companies, which do not have much funding to hire new people every year'. (FG6).

The perspective of the company regarding scientific research and academia is mentioned as a potential challenge because the integration in an industrial context depends on how the company assesses the relevance of scientific research.

'Not all companies have this vision, or the ability to realize the importance of day-to-day research on a company and how it can evolve with it. (…) In Portuguese companies I think that this business vision of the importance of research is still lacking.' (FG6).

Personal attributes and acquired competences

During the focus group discussions, the students referred both to personal attributes, which they thought were necessary for a student enrolled in an industrial doctorate, as well as to competences that they acquired during their doctoral studies and which set them apart from students in traditional trajectories.

Regarding personal attributes, *flexibility* stood out as the most frequently mentioned characteristic. Flexibility is necessary for these students because they develop their research in multiple environments and have to adapt and respond to diverse needs and interests coming from academic supervisors and the partner company. Students described themselves as polyvalent since they do not only have to conduct research but they must also be able to tune in a different mind-set typical of an industrial environment, as the following transcript shows:

'For example, I think that a doctoral student at both academic and industry level has to possess some characteristics in order to know how to do the job, to have that ability to adapt, to get to work on the tools and to take these tools and adapt them to the type of work you are doing. For example, in my case, I did data processing, did optimization, programming, I'm working with several tools that are not only applied to my project, but can also be adapted to another type of company, another type of industry and I have this ability to use the tools and adapt them to various situations and use them to solve business problems'. (FG5).

Another personal attribute that was mentioned by students, although with less emphasis, was *resilience*. This is understood as a fundamental attribute when dealing with the many challenges and difficulties posed by the company's presence as an actor with a stake in the research. The students referred to the inaccessibility and lack of time of industry representatives and felt

persistence was necessary to get the information and input they needed. The hosting and integration process in the companies is described as a complex task and the most challenging and the main limitation of an industrial PhD.

They also spoke of a different rhythm as far as research was concerned in an industry context.

> 'We also talked about persistence ... (...), we also have to have a lot of persistence, because it will be a solitary job, always knocking on the door of the company, for them to help us, and give us the data that we need. (...) For this [doctoral programme], in particular, it has to be the persistence, which has to begin early in the first year. The question is to overcome the difficulties that arise in a company in the context of research. And we know things have their normal rhythm there, don't they? It's almost like setting an aircraft carrier in motion. It takes a little while to start moving'. (FG1).

Resilience and flexibility are also necessary because the definition of the research topic and the research plan is perceived as a complex negotiation between students' own research interests and the interests and expectations of the company.

> 'We have freedom, but it is a conditional freedom. In a traditional doctorate you have your interest and the interests of your supervisor and you discuss with him how to put it into practice. In an industrial PhD, we must always take into account the business and the interests of the company.' (FG3)

The different expectations of academia and industry also appear to lead to uncertainty regarding research outputs. In some cases, students do not know what is expected to achieve by the end of the research: a traditional thesis or a patent or a collection of scientific articles.

> 'If the results were already defined ... but they are not. It gave us a little more security, we already knew what they expected from us. (…) This is not written at all and we do not know ...' (FG2)

Other characteristics which were underlined, with less weight than the previous ones but in an equal measure between them, were proactivity (taking initiative), learning autonomy (capacity to search for relevant knowledge) and an entrepreneurial mind-set (related to being business- and output-oriented, aware of costs and benefits and the real world context). This last characteristic is indicative of the industry culture which students are exposed to.

In fact, gaining knowledge of the *industry culture* emerged as the most important acquired competence during this kind of doctorate. Multiple dimensions of this culture were highlighted, but the greatest emphasis lay on the focus on commercialisation through the application of knowledge in order to create a product/service and learning about what this entails (patents, copyright, certifications, market research, etc.).

> 'I think this type of programme allows people to have some sensitivity, maybe some more than others, depending on the project you are doing. You start to have some idea of the

value of things and how you can introduce new technologies, which may be discovered in the laboratory, into the market.' (FG6).

Industry culture also implied learning about the dynamics and the organisation of a private company, becoming more aware of the costs and benefits of every activity, and feeling the need to develop their research so as to be oriented towards objectives and towards solving the problems raised by the companies.

> 'For me it was a very vast learning. I think it is very complete. I could understand not only the whole manufacturing process, which has a lot of interest, but also the way the business fabric is organised, the various departments, and I think that's a plus. First because it does not limit our knowledge as we here have a way of working that is the proper form of research. We know how things work at the level of the university, the laboratories in particular, and we manage at the same time to adapt, or to learn what the reality is, let's say so. It turns out to be our intention to do something here that can be transposed'. (FG3).

Besides the knowledge of the industry culture, the second most important acquired set of skills and abilities referred to by students were the *transferable skills*, which could be applied to a wide range of different jobs and industries. These skills include, in descending order of relevance, networking (a wide range of contacts both in academia and in industry), communication (to sell and to justify their ideas and the outcomes of their research), negotiation (the ability to reconcile different and, in some cases, conflicting interests), team work (through which students develop conflict resolution skills) and, with less emphasis, flexibility, writing skills and autonomy. These skills are fully aligned with those described in the literature and which are related to the business environment and its precise end goals, tight deadlines, teamwork and multi-tasking required by the involvement in several projects (Lee, Miozzo & Laredo, 2010). Indeed, these skills are, as Wardenaar et al. (2014) argued, broader and more aligned with industrial activities of commercialisation and application of knowledge. The following transcript illustrates the importance attached to networking:

> 'The advantage ends up being that of working with other entities, which allows us to gain knowledge. We end up having more than one working group, not only here in the University, but also in another working group. Being in collaboration with Zurich, I have not only my supervisor, but also the working group that he guides. And we all contribute to the same work. I'm not just in touch with my supervisor. I have other people, we are always collaborating. Getting to know people from different worlds, and from different areas, to see how it works, I think this is quite beneficial. The company level also turns out to be the same thing ... contact with the company ...' (FG 4).

Although not emerging in focus group discussions as prominently as the two previous competences – gaining knowledge of the industry culture and transferable skills –,

entrepreneurship, which had already been mentioned as a personal attribute, was also a competence that students deemed to develop within this type of doctorate.

> 'For me it was a novelty reaching a stage of development of the *start-up* and selling it. I had no idea that this was common in other countries. For example, in the US, people develop the idea, work on it for a while, and then go to a big company and say they have that idea and they want to sell it. This is one of the things that we learned here and which I found interesting'. (FG6).

Other students, while recognising the importance of gaining knowledge of the industry culture, did not forget the relevance of the academic environment, highlighting the meaning of gaining knowledge of the *dual culture* (academia and industry).

> 'I did a doctorate, but I'm not theoretical person, because I did a doctorate in industry. So I keep on having the perspective of research and of the academic career because it is still a doctorate after all. Additionally, I have the perspective of industry because I did a doctorate in the industry and I'm not as theoretical as the other doctorates at the university. And that's a big gain.' (FG4).

Although professional experience did not emerge with much weight in the focus group discussions on the criteria for admission to industrial doctorates (alongside knowledge of the English language and the relevance of the discipline), the fact is that 70% of the participants in these discussions had some previous professional experience. In this sense, having previous knowledge of the business environment can be a factor that influences the choice of this type of doctorate and increases the possibility of getting accepted on the programme.

Conclusion

The aim of this study has been to explore the perceptions of Portuguese students enrolled in industrial doctorates in order to analyse their profile regarding what motivates them, what they expect, who they are and who they intend to become.

Indeed, students enrolled in these doctorates seem to be mainly extrinsically-motivated, which means that they perceive their research as a product with potential to be commercialised. Students enrolled in industrial doctorates think that they benefit from having contact with the dual culture, which tends to broaden their career prospects, turning them more promising than those of their colleagues enrolled in traditional doctorates. The degree is therefore perceived in an instrumental way, since its value is understood according to the opportunities it fosters.

However, opportunities appeared to students as more feasible in industry rather than in academia, where jobs are very scarce and where their competences are not as valued as in industry. Students believe that some of these competences define who they are and determine a successful completion of the doctorate: flexibility, resilience or proactivity are perceived as key personal attributes to enrol and to achieve the goals of an industrial doctorate. Besides these competences,

students also believe that, through these kind of doctorates, they develop an additional set of competences that set them apart from other doctoral students: the knowledge of the industry culture (dynamics, problem-solving or commercialisation), transferable skills (networking, communication or negotiation) and entrepreneurship (such as start-up development). Students therefore believe that they will become both employable and potential entrepreneurs.

The profile of Portuguese industrial doctorate students has therefore a great potential to act as bridge builders between two apparently distant worlds, such as academia and industry. Students develop a more *pragmatic* profile focused on combining synergies, taking advantage of academic research tools to solve real-world problems. This profile supports and gives robustness to the bridge between academia and industry which they represent and points to the emergence of a different professional identity than the one typically associated with PhD holders. For this reason, this study suggests that industrial doctorates are a means of contributing to the development of a multifaceted researcher capable of and willing to perform research in industry (De Grande et al., 2014).

Notes

[1] Currently, authors talk about a quintuple helix (see Carayannis, Barth & Campbell, 2012) and even about an N-tuple helix (see Park, 2014).

[2] Very recent legislation allows polytechnics to award doctorates under very restricted conditions (the capacity of the institution to carry out R&D activities and to have at least 75% of the human resources integrated into research units. A minimum evaluation of "Very Good" by the Foundation for Science and Technology (FCT) is also required.

References

Ashraf, R. U., Hou, F., Kirmani, S. A. A., Ilyas, M., Zaidi, S. A. H., & Ashraf, M. S. (2018). Student employability via university-industry linkages. *Human Systems Management*, *37*(2), 219-232.

Bienkowska, D., & Klofsten, M. (2012). Creating entrepreneurial networks: academic entrepreneurship, mobility and collaboration during PhD education. *Higher Education*, *64*(2), 207-222.

Borrell-Damian, L., Brown, T., Dearing, A., Font, J., Hagen, S., Metcalfe, J., & Smith, J. (2010). Collaborative doctoral education: University-industry partnerships for enhancing knowledge exchange. *Higher Education Policy*, *23*(4), 493-514.

Borrell-Damian, L., Morais, R., & Smith, J. H. (2015). *Collaborative Doctoral Education in Europe: Research Partnerships and Employability for Researchers Report on Doc-Careers II Project*. Brussels: European University Association.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in*

Psychology, *3*(2), 77–101.

Briscoe, J. P., Hall, D. T., & DeMuth, R. L. F. (2006). Protean and boundaryless careers: An empirical exploration. *Journal of vocational behavior*, *69*(1), 30-47.

Carayannis, E. G., Barth, T. D., & Campbell, D. F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of innovation and entrepreneurship*, *1*(1), 2.

Carayannis, E. G., Campbell, D. F., & Rehman, S. S. (2016). Mode 3 knowledge production: Systems and systems theory, clusters and networks. *Journal of Innovation and Entrepreneurship*, *5*(1), 17.

Cardoso, S., Tavares, O., & Sin, C. (2019). Can you judge a book by its cover? Industrial doctorates in Portugal. *Higher Education, Skills and Work-Based Learning*. DOI: 10.1108/HESWBL-05-2018-0056

Carvalho, T. (2012). Shaping the 'new' academic profession. Tensions and contradictions in the professionalisation of academics. In G. Neave & A. Amaral (Eds.), *Higher education in Portugal 1974-2009. A nation, a generation* (pp. 329-352). Dordrecht: Springer.

Celis, J., & Duque, M. (2016). Factores que configuran las preferencias de empleo de los estudiantes de doctorado en ingeniería por la academia y la industria. *Investigación y Desarrollo*, *24*(2), 355-385.

Clark, B. R. (1998). *Creating Entrepreneurial Universities: Organizational Pathways of Transformation. Issues in Higher Education*. New York: Elsevier.

De Grande, H., De Boyser, K., Vandevelde, K., & Van Rossem, R. (2014). From academia to industry: are doctorate holders ready? *Journal of the Knowledge Economy*, *5*(3), 538-561.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ''Mode 2'' to a Triple Helix of university-industry-government relations. *Research Policy* 29, 109–123.

European Commission. (2011). *Report of Mapping Exercise on Doctoral Training in Europe "Towards a common approach"*. Brussels: European Commission.

FCT – Fundação para a Ciência e a Tecnologia (2018). "Doctoral programmes", available at: https://www.fct.pt/apoios/programasdoutoramento/index.phtml.pt (accessed April 2018).

Fritsch, M. & Krabel, S. (2012). Ready to leave the ivory tower? Academic scientists' appeal to work in the private sector. *The Journal of Technology Transfer*, *37*(3), 271-296.

Gibbons, M., et al. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage.

Hancock, S., Hughes, G., & Walsh, E. (2017). Purist or pragmatist? UK doctoral scientists' moral positions on the knowledge economy. *Studies in Higher Education*, *42*(7), 1244-1258.

Harman, K. M. (2004). Producing 'industry-ready' doctorates: Australian Cooperative Research Centre approaches to doctoral education. *Studies in Continuing Education*, *26*(3), 387-404.

Heitor, M., Horta, H., & Mendonça, J. (2014). Developing human capital and research capacity: science policies promoting brain gain. *Technological Forecasting and Social Change*, *82*, 6-22.

Henkel, M. (2007). Can academic autonomy survive in the knowledge society? A perspective from Britain. *Higher Education Research & Development, 26*(1), 87-99.

Hennink, M. M. (2013). *Focus group discussions*. Oxford University Press.

Kihlander, I., Nilsson, S., Lund, K., Ritzén, S., & Bergendahl, M. (2011). Planning industrial PhD projects in practice: Speaking both "academia" and "practitionese." In *DS 68-8: Proceedings of the 18th International Conference on Engineering Design (ICED 11), Vol. 8: Design Education*. Lyngby/Copenhagen, Denmark, 15-19.08.2011.

Lee, H. F., & Miozzo, M. (2015). How does working on university–industry collaborative projects affect science and engineering doctorates' careers? Evidence from a UK research-based university. *The Journal of Technology Transfer*, *40*(2), 293-317.

Lee, H., Miozzo, M. & Laredo, P. (2010). Career Patterns and Competences of PhDs in Science and Engineering in the Knowledge Economy: The Case of Graduates from a UK Research-Based University. *Research Policy, 39*(7), 869–881.

Lee, S. A. (2008). Increasing student learning: A comparison of students' perceptions of learning in the classroom environment and their industry-based experiential learning assignments. *Journal of Teaching in Travel & Tourism*, *7*(4), 37-54.

Lepper, M. R. (1988). Motivational considerations in the study of instruction. *Cognition and instruction*, *5*(4), 289-309.

Manathunga, C., Pitt, R., Cox, L., Boreham, P., Mellick, G., & Lant, P. (2012). Evaluating industry-based doctoral research programs: perspectives and outcomes of Australian Cooperative Research Centre graduates. *Studies in Higher Education*, *37*(7), 843-858.

Nash, J. M. (2008). Transdisciplinary Training. Key components and prerequisites for success. *American Journal of Preventive Medicine*, 35, 133–140.

Offerman, M. (2011). Profile of the nontraditional doctoral degree student. *New directions for adult and continuing education, 129*, 21-30.

Kyvik, S., & Olsen, T. B. (2012). The relevance of doctoral training in different labour markets. *Journal of Education and Work*, *25*(2), 205-224.

Park, H. W. (2014). Transition from the triple helix to N-tuple helices? An interview with Elias G. Carayannis and David FJ Campbell. *Scientometrics*, *99*(1), 203-207.

Pinheiro, R., Langa, P. and Pausits, A. (2015). The institutionalization of universities' third mission: introduction to the special issue. *European Journal of Higher Education*, 5(3), 227-232.

Roach, M., & Sauermann, H. (2010). A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry. *Research policy*, *39*(3), 422-434.

Roberts, A. G. (2018). Industry and PhD engagement programs: inspiring collaboration and driving knowledge exchange. *Perspectives: Policy and Practice in Higher Education*, *22*(4), 115-123.

Salminen-Karlsson, M., & Wallgren, L. (2008). The interaction of academic and industrial supervisors in graduate education. *Higher Education, 56*, 77-93.

Santiago, R., Carvalho, T., & Ferreira, A. (2015). Changing knowledge and the academic profession in Portugal. *Higher Education Quarterly, 69*(1), 79-100.

Santos, P. (2016). Moving the Universities to the "Third Mission" in Europe, New Impulses and Challenges in Doctoral Education. *Foro de Educación*, 14(21), 107-132.

Santos, P. (2017). Pensar a reconfiguração do ensino doutoral na interface universidade-empresa: contextualização e proposições teórico-empíricas. CIES e-Working Paper Nº 208/2017. ISCTE. Lisboa.

Seibert, S. E., Crant, J. M., & Kraimer, M. L. (1999). Proactive personality and career success. *Journal of applied psychology*, *84*(3), 416.

Slaughter, S. A., & Rhoades, G. (2004*). Academic capitalism and the new economy: Markets, state, and higher education*. JHU Press.

Smith, R., Mackay, D., Holt, D., & Challis, D. (2008). Expanding the realm of best practices in cooperative industry-based learning in information systems and information technology: an inter-institutional investigation in Australian higher education. *Asia-Pacific Journal of Cooperative Education*, *9*(1), 73-80.

Tavares, O., & Ferreira, J. B. (2012). Choices and Motivations: the why and how of Portuguese students' enrolment choices. *European Journal of Education*, *47*(2), 310-326.

Tavares, O., Cardoso, S., Carvalho, T., Sousa, S. B., & Santiago, R. (2015). Academic inbreeding in the Portuguese academia. *Higher Education*, *69*(6), 991-1006.

Thune, T. (2010). The training of "triple helix workers"? Doctoral students in university–industry–government collaborations. *Minerva*, *48*(4), 463-483.

Thune, T. (2009). Doctoral students on the university–industry interface: a review of the literature. *Higher Education*, *58*(5), 637.

Wardenaar, T., Belder, R., de Goede, M. E. E., Horlings, E., & van den Besselaar, P. (2014). Skill development in collaborative research projects: A comparison between PhD students in multi-actor research programs and in traditional trajectories. In T. Wardenaar (Ed.) *Organizing Collaborative Research* (pp. 108 – 129). Den Haag: Rathenau Instituut.