Intersectoral collaborations of doctoral researchers and generic skills acquisition

A critical realist inquiry

by

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Summary

This dissertation aims to enrich the academic knowledge that can support policies around integration of doctoral graduates as a prominent group of knowledge workers, into industry and other non-academic career sectors in Europe. Positioned within the broader field of innovation systems, the dissertation contributes to the literature stream of university-industry relationships with a specific focus on the collaborative relations between doctoral researchers and industry. Given the observation that the number of doctoral graduates in Europe is continuously increasing while the opportunities for pursuing an academic career do not show a comparable trend, the importance of preparing doctoral candidates for a more diverse career prospect is evident. Furthermore, the drive for transitioning to a knowledge-based and innovative economy has meant for many European countries that knowledge sources in general, and universities in particular, have gained a more prominent position vis-à-vis the other sectors in their economy. Accordingly, there is an increasing space opening up across advanced economies for the employment of doctoral graduates in industry and public governance positions in order to absorb their knowledge and skills into those organizations. While this has provided doctoral graduates further potential for post-PhD employment, there has been concerns expressed by those non-academic employers regarding the mismatch

between the skills sought by them and the skills acquired by PhD candidates during their doctoral training.

The four papers included in this dissertation form together a stepwise inquiry into the rationale, quiddity, prevalence and immediate effects of collaborative doctoral programmes as a mechanism for addressing the above-mentioned concerns about doctoral education. As the overall underlying research paradigm, critical realism provides the framework for establishing a coherent inferential logic across the papers, in addition to supplying the meta-theory for comprehending the subject matter of the inquiry and interpreting the findings. The introductory chapter of the dissertation is partly dedicated to explicating the argument for choosing such a critical realist approach, which mainly stems from academic disciplines being conceived as harboring a generative mechanism that hypothetically exert the most significant influence on doctoral researchers' opportunities for engaging in intersectoral collaboration. In fact, the theoretical core of the last three papers in the dissertation is constituted of alternative hypotheses on the significance of academic knowledge fields (disciplines) in shaping the collaboration opportunities and behavior of doctoral researchers, and whether such a significance is consistent across all the disciplinary groups. Accordingly, the last two papers empirically investigate to what extent the disciplinary factor functions consistently across different higher education contexts in a deterministic manner, and how the learning experience of doctoral researchers from participating in collaborative schemes is formed by disciplinary and context-driven factors.

Findings of this dissertation can be summarized as follows; i) there exists skepticism among industrial employers regarding the preferability of doctoral graduates over, for instance, postgraduates with master's degree, as the skills set of the former are deemed too focused, and their attitude is perceived as less flexible. Furthermore, among doctoral graduates, those who have experienced collaborative doctorate programmes such as Industrial PhD are often preferred by industry; ii) the systemic attributes of the intrasectoral and intersectoral relations in which university-industry collaborations materialize has influence on the type and efficiency of those collaborations around doctoral training. The higher level of consensus among the system actors facilitates practice-based acquisition of transferable skills for doctoral students; iii) the extent to which affiliation with a specific academic disciplinary area affects the opportunities of doctoral researchers for intersectoral collaboration can be different depending on the discipline. In the case of the four universities studied in the Scandinavian context, hard-applied and soft-pure disciplines appeared more susceptible to the influence of contextual (local) factors on the disciplinary factor and its mechanism, while hard-pure and soft-applied disciplines seem to exert comparable influence on the intersectoral collaboration opportunities across different country contexts; therefore, iv) higher education policies targeting the improvement of intersectoral collaborations during doctoral education need to take into account the heterogeneity of academic disciplines in terms of their receptivity of different policy tools. While for some disciplines, introducing interdisciplinarity can be the main option, for

others, improving the organizational and institutional aspects of the collaborations would help more. I have referred to this heterogeneity as discrepancy between the discipline-based regimes of intersectoral collaboration; v) when it comes to the learning of generic (transferable) skills through collaborative schemes during doctoral education, their co-development with the disciplinary knowledge seems to be a key condition. The cognitive interrelation between some of the generic skills and the discipline-specific skills proves to be so strong that make parallel and balanced development of generic and disciplinary skills more important than other factors such as the duration of collaboration or its funding composition. In other words, the commitment of the non-academic side of the collaboration shows its influence more through dedication of resources such as industrial supervisor who can facilitate coordination of data and knowledge exchange between the two collaboration sides and harmonize the acquisition of generic and discipline-specific skills by doctoral candidates.

Further to the above-mentioned findings, this dissertation puts forward an analytical conceptual framework adapted from critical realism, based on which the evaluation of (collaborative) doctoral programmes is done by distinguishing between contextual and disciplinary mechanisms as well as their outcome in terms of learning. The emphasis on the contextuality of explanations, and that such explanation is just better than the rival ones, are aspects which make such a framework suitable for implementation in other studies for further investigations of the matter. Finally, a key message from this dissertation is that for enriching doctoral

education with providing doctoral candidates a comprehensive set of generic skills, there is a need for more intensive involvement of industry in the design of collaborative schemes, and the organizing for this needs to be done at the level of academic departments or faculties rather than graduate schools at the university level.

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Paper II: Moghadam-Saman, S. (2020). Collaboration of doctoral researchers with industry: a critical realist theorization. *Industry and Higher Education*, 34, pp. 36–49.

Paper III: Moghadam-Saman, S. (n.d.)**.** Intersectoral engagement of doctorands: Regime discrepancy between the Academic Territories. Manuscript submitted to *Higher Education Policy*.

Paper IV: Moghadam-Saman, S. (n.d.)**.** How collaborative doctoral programmes foster acquisition of generic skills? – Professional Doctorate versus Industrial PhD. Manuscript ready for submission.

1 Introduction

Technological innovation has come to be seen as a paramount factor of economic growth, at least since Robert Solow's 1957 article on the influence of technical change on productivity. Concomitantly, *innovation* became a subject of scholarly studies more clearly since the 1950s (Rothwell, 1994). In fact, putting aside the seminal works on innovation economics by Joseph Schumpeter during the first half of the 20th century, the broader research field of *innovation studies*, which was originally better known as *science policy research*, has been developing since the late 1950s (Martin, 2016; Fagerberg and Verspagen, 2009). While since its inception, the scholarly interest in this field has been increasing steadily, the growth of such interests has been specifically significant since the early 1990s (Fagerberg and Verspagen, *ibid*). This has in fact coincided with one of the most important advances made since the inception of the research field, which is related to the progress made from concentrating solely on the individual innovation actors - such as firms or universities – to the inclusion of the linkages between them (Martin, 2010). This has come to mean that, during the second half of the innovation topic's lifetime so far, innovation scholars' perception of innovation processes has evolved from "for company" models to "for economy" models (Meissner and Kotsemir, 2016). These latter models can be referred to as *system models*, which instead of focusing on firm-level operational management tools - which was the main studied subject of the former models - problematized *framework conditions* at different

levels (e.g. national, regional, sectoral) that can be conducive to innovation (Meissner and Kotsemir, *ibid*). While one can attribute the majority of seminal innovation literature at the firm level to North American scholars, the system-level literature has been dominated by European authors (Fagerberg *et al*., 2012).

Freeman (1987), Lundvall (1992) and Nelson (1993) are credited with providing the initial scholarly inputs to the systemic understanding of innovation phenomenon. Surveying eleven authoritative handbooks written on the topic of innovation studies between 1993 and 2010, Fagerberg *et al*. (2012) found that Nelson's 1993 work on national innovation systems has hitherto been the second most important contribution to the field according to the experts of the topic. Lundvall (2013a) has taken the importance attached to the systemic understanding of innovation to a level where he considers the 'conceptualization of *innovation as an interactive process*' – in contrast to the R&D focused linear model - to constitute *the* theoretical core in innovation studies (p. 13). In line with this, where Lundvall (2013b) identifies three main streams of literature within innovation studies, including a techno-economic, an evolutionary, and a socio-economic approach, he considers this third one, which pays specifically more attention to interactive learning, as being particularly promising as a platform for further progress in the field of innovations studies. Congruent with this, Lundvall considers one of the main challenges ahead of the field of innovation studies to be linking innovation performance to the specificities of labour markets and education institutions (Lundvall,

2013b). He then goes on to highlight education and labour market policy as one of the research areas towards which the borders of the field of innovation studies needs to open up.

In harmony with the aforementioned developments in the field of innovation studies, the science, technology, and innovation (STI) policies - or as it is put more simply, *innovation policies* - have also evolved from the linear understanding of innovation process with clear division of labour for different actors (such as scientific institutions, economic entities, government), to a model in which these actors interact more closely in order to create an interactive learning environment between them and build up absorptive capacities (Schot and Steinmueller, 2018). Educating and training a workforce which can enhance the absorptive capacity of the firms and other organisations interacting with them, then, became a target for government innovation policy.

The evolution from R&D-focused innovation policy to system-oriented innovation policy meant that, next to remedying the market failure, the innovation policies need to address system failures, i.e. the lack of cooperation and coordination among the actors of the innovation system. Accordingly, the government policies aiming at innovation system build-up need to establish and strengthen mechanisms "[…] for 'wiring up' national systems of innovation by getting the players to talk to each other more than they had done in the past" (Martin, 2010, p. 5).

Accordingly, a systems approach to understanding, analyzing and planning innovation emerged in the latter decades of the past century, the application of which in research and policy prevails till the date. Flanagan *et al*. (2011) point out that the debate around innovation policy has moved toward *policy mix*, meaning that interactions and interdependences between different policy areas which affect innovative performance of an innovation system as an outcome, have taken the centre stage. Higher education policies are undoubtedly one key element in such innovation policy mixes, especially in the form of regulatory instruments (Borrás and Equist, 2013).

Systems of innovation approach has been characterized by having interactive learning and evolutionary theories of technical change at its origins (Edquist, 1997). Aiming at competence building, those learning stimulation activities include, in addition to organizational learning, provisions for *individual learning*, through training the labour force for innovation and R&D activities (Edquist, 2019). This kind of provisions for knowledge inputs to the innovation process comprise one of the key activities in systems of innovation (Edquist, *ibid*).

Galan-Muros and Plewa (2016) count seven categories of activities for university-business cooperations (UBCs), three of which belong to the education category, including curriculum design and delivery, lifelong learning, and student mobility. Two others of these activities, then, are related to research, namely professional mobility between the sectors, and R&D collaborations. Additionally, within the valorization context,

the authors also refer to two type of activities, including entrepreneurship and commercialization of R&D. Galan-Muros and Plewa (*ibid*) then study the drivers and barriers of UBCs in Europe, and show that compared to collaborations which are of an educational type, the lack of appropriate contacts between the two sectors is much more significant for research- and valorization-oriented activities. This is corroborated by the results of a survey of UBCs in Europe conducted by the EC (2018), which shows that among the four UBC areas (education, research, valorization, and management), the higher education institutions' representatives perceive the education-related UBC to be the most developed area, followed by the research-related UBC. This observation also resonates with the findings by Perkmann and Walsh (2009, p. 35) where they advocate for multiplicity in the interaction types of academics with industry, rather than one-off consulting or contract research activities. According to them, "[…] learning effects from practical engagement with industry would appear most pronounced if pursued in conjunction with other, more research-focused types of collaboration".

Meyer-Krahmer (1997) points to the problems arising at the interface points in the innovation system, e.g. those between academia and industry, for instance due to their differences in terms of research processes. But this challenge is in fact one of the main *raison d'être* for innovation systems, as the interactions between the system components are supposed to facilitate the mutual understandings. In line with this, one of the more prominent conceptual frameworks which appeared in line with the systemic understanding of innovation process was the

Triple Helix (TH) model of Etzkowitz and Leydesdorff (1995). This framework emphasized the growing trend of knowledge exchange between universities, industries and governments, and considered this to be the core of knowledge production and technology innovation (Etzkowitz and Leydesdorff, 2000). Etzkowitz (2003) explains that the two main starting points for the formation of TH system includes statist model and laissez-faire model. While in the former model, academia and industry are driven by government, and change in ideology often precedes changes in structure, in the latter one, it is industry which is usually the driving force, and practice is often ahead of ideology. A reform then leads to each of these two models to evolve into a TH system with balanced role of the three helices. In fact, the TH model elevated university to an equivalent status with industry and government in a knowledge-based society, and advocated for blurring the institutional boundaries among these three sectors, facilitating the sharing of various resources, including the human resources, among the parties of a TH system. Not surprisingly, Etzkowitz notes that such interactions mostly occur at the regional level. In a more systemic development, the innovation-oriented interactions between the various TH institutional spheres can lead to the formation of multi-sphere (hybrid) institutions such as science parks and business incubators (Ranga and Etzkowitz, 2012). Furthermore, when those interactions take place with the preserving of the independence from the state, an entrepreneurial university can emerge, embodying various forms of liaison units with

business, such as quasi-firm research groups, technology transfer offices or incubators (Etzkowitz, 2003).

As indicated earlier, provisions for 'individual learning' with the aim of training a skilled labour force for innovation activities constitutes a key function of innovation systems and the policies targeting their performance enhancement. Systemic models like Triple Helix, then, facilitate the training of these labour forces to be done in joint arrangements between the institutional spheres through providing opportunities for intersectoral mobility and collaboration. Logically, it can be said that the earlier these joint trainings take place during the career of research and innovation human resources, the more will be the possibility for them to plan for intersectoral career mobility. Accordingly, early stage researchers are best positioned to experience intersectoral research collaborations with the purpose of skills acquisition.

Thune (2010) discusses how the advent of TH systems, in addition to the labour market realities and the changes on the mode of knowledge production, has meant for doctoral students to be increasingly trained as "Triple Helix Workers". In her paper, Thune combines findings from a review of previous empirical studies on university-industry interfaces as a context for researcher training, with her own investigation of the matter. One of the conclusions is that "[i]n general, it seems fair to conclude that collaborating with industry during the PhD has limited impact on study experience and outcomes realized during the PhD

period, but that it has long term impacts on career patterns" (p. 7). This observation can be perceived as implicitly referring to an unobserved factor stemming from collaborative doctorates that influences the career pathways of doctorate holders. In line with this, Thune herself points, among some other areas for further research, to the need for studies on the impact of researcher training in the triple helix context on gaining competences other than those acquired by non-collaborating doctoral students. In fact, collaborative PhD programmes can lead to the emergence of a different professional identity than the one typically associated with PhD holders (Tavares *et al*., 2020). This would imply that innovation systems, when functioning in accordance with their systemic traits, can extend their impact to the level of individual agents, in addition to influencing the structures. Thune (2009) herself conducted a literature review on the role of doctoral students on the university-industry interface, and the experience and outcome they acquire from those interactions. Her investigation of the hitherto empirical research on the issue found four variables to be important in each of the three categories of preconditions, interaction, and outcomes of such interactions. For the preconditions, it was found to be about firm characteristics, disciplinary characteristics, student characteristics, and prior experience. In case of the interaction, the organizational arrangement, the supervision arrangement, the resource exchange, and the negotiation of differences were found to be crucial. Finally, as to the outcomes, the prior empirical research had pointed to the significance of study satisfaction, study outcomes, career ambitions, and career

trajectories. Consequently, Thune comes up with some propositions for further research, among which two are related to doctoral students' experience from the collaboration with industry. These two propositions suggest that involved parties' prior collaboration experience, as well as the degree of institutionalization of their collaborative agreement, condition doctoral students' experience and study outcome from the university-industry interaction. Related to these, the author emphasizes the need for sampling more varied collaborative arrangements, since these provide different contexts for such collaborations.

When the purpose of investigating the variety in collaboration arrangements of doctoral researchers with industry – or generally, with non-academic sectors - is to propose policies for improvement of the impact of those collaborations, a deeper insight can be acquired by trying to understand the factors underpinning the emerging of such a variety of arrangements in the first place. From the perspective of innovation systems, interactive learning can be seen as the main outcome sought from the collaborative arrangements. At the abstract level, the most obvious dimension which makes a distinction among academics' learning process is their disciplinary affiliation (Donald, 2002). This makes the disciplinary factor a logical candidate to be examined with regards to its influence on the variety found in academics' intersectoral collaboration arrangements.

D'Este and Patel (2007) have shown that the proportion of researcher interacting with industry is different across academic disciplines. Their

findings point, for instance, to the higher frequency of collaborations with industry among academics of engineering fields compared to those from physics and mathematics. Larivière *et al*. (2006) showed, through their study of Canadian academics, that inter-institutional collaborations of social sciences researchers resemble more that of natural sciences and engineering, rather than that of humanities.

Scholars have argued that at universities, the disciplinary professional practices and cultures are institutionalized and reflected at the faculty and department level (Clark, 1987). Hence, it is a plausible assumption to expect varying levels of collaboration with industry across faculties and departments. The disciplinary factor, however, does not exert its seemingly significant influence in a mono-causal space. In fact, academic departments need to be seen as complex systems nested into a broader system, i.e. the overarching university structure, which in turn are nested in, and are increasingly accountable to broader systems (Bento, 2013). And since these broader societal systems are confronting sophisticated sustainability issues, the academic leadership needs to extend its vision to 'understanding how transformative learning take place in academic environments' with the goal to be internally adaptive to the external changes (Bento, *ibid*, p. 189). Here, transformative learning refers to a redesigning of the education systems, in such a way that the learning becomes capable of corresponding to those transformations society undergoes due to sustainability concerns.

When it comes to the training of doctoral students, then, the arguments above would imply that while the disciplinary area of the research is a prime suspect for influencing their chance of landing a collaborative doctoral project more than any other factor, contextual factors like the higher education policy command further causality. This would, in other words, imply that doctoral students conducting research within a similar scientific field might not necessarily face a similar level of industry collaboration opportunities if they are positioned in disparate institutional contexts (cf. Neumann and Tan, 2011). Access to funding is usually mentioned as one of the key factors differing across different higher education contexts. Bozeman and Gaughan (2007), for instance, observed that "academic researchers who have research grants and contracts work more extensively with industry than those without grants or contracts" (p. 704). Consequently, it can be argued that the learning experience acquired through collaborative doctoral programmes would likely differ, not only between doctoral researchers affiliated with different disciplinary units, but also between those conducting research within the same disciplinary area positioned in different institutional and system-level policy contexts. In congruence with the main function of innovation systems, when it comes to the engagements of doctoral researchers with industry, the main purpose is making enhancement in their learning of skills pertaining to the employability in industry (Harman, 2010; Kyvik and Olsen, 2012; Hancock and Walsh, 2016). Aiming at the enrichment of higher education policies targeting doctoral

graduates' skills in Europe, this doctoral dissertation aims to find an answer for the following research questions;

- How prevalently are industry collaboration schemes used by doctoral researchers across different academic departments?
- What is the actual learning experience of doctoral researchers from different industry collaboration schemes, in terms of the acquisition of transferable skills?
- How can higher education policies at the national and university level help improve exploitation of learning opportunities for doctoral researchers from their collaboration with industry?

2 Past research

The above-mentioned main research questions of this doctoral dissertation make it clear that the matter of learning through intersectoral, and mainly university-industry collaborations (UICs) constitutes the phenomenon subject to inquiry here. This is a classical topic for research within innovation systems since, as mentioned earlier, scholars of innovation systems put the issue of learning at the centre of their comprehension and analysis of those systems. What is more specific to this dissertation in relation to the broader research area of innovation systems, is its focus on *doctoral researchers'* learning through UICs. Ontologically, however, a connection can be established here with similar inquiries on the issue of individuals' interactive learning at the other stages of education or academic career. Generally, it has been argued that university-industry relationships are of recursive nature, and specifically during applied research projects, interactions lead to mutual learning (Perkmann and Walsh, 2009). Such a combining of the engagement with knowledge producing and knowledge using sectors helps to establish a better balance between the theoretical and practical elements within the education system, a condition which in turn can make workplace learning thrive in countries (Lundvall *et al*., 2009).

Based on the above prelude, it would be reasonable to consider relevant to the current research the academic literature that have investigated in the past the subject of academics' engagement with other sectors, and their learning and upskilling through such engagements. Related to this,

then, the literature dealing specifically with the engagement of doctoral researchers in the UICs would add a more focused overview. Compared to the richness of literature on UICs, the literature on the engagement of doctoral researchers with industry is more limited. Hence, in case of the former, the goal here will be to attain a grasp of what the systematic literature reviews have presented on the subject. Thereafter, an overview of the past research on the collaborative doctorates with industry, and the issue of acquiring generic skills, follows in a more open review approach.

Literature on university-industry collaborations

After the emerging of systems of innovation approach in theory, practice and policy spheres, the literature on university-industry links and collaborations has grown steeply. For instance, in the UK, the volume of this literature has increased significantly after the introduction of a number of major policy measures in the mid-1990s (Calvert and Patel, 2003). The body of knowledge, however, contains a considerably wide range of linkage types and characteristics. There exist scholarly publications which have paid attention to the issue of conceptual clarification of the subject, notably the systematic reviews by Perkmann and Walsh (2007) and Ankrah and AL-Tabbaa (2015). Since the UICs can comprise a very broad set of relations between the two sectors, these two review papers are given priority in the inquiry here.

Perkmann and Walsh (2007) reviewed empirical articles on UICs published from 1990 onwards, and made a clear distinction between

university-industry *relationships* and university-industry *links*, explaining that the notion of links includes more generic type of interactions between the two sectors, which can include also a lower relational involvement from the two sides, such as transfer of intellectual property, or scientific publications. The authors then provide a more nuanced typology of university-industry links based on the extent of relational involvement, in which such links are divided to three levels with high, medium and low relational involvement. These three levels are referred to, respectively, as relationships, mobility, and transfer. Accordingly, UI relationships include research partnerships and research services, whereas mobility refers to academic entrepreneurship and human resource transfer (which can be permanent or temporary), and the last category, i.e. transfer, is basically about commercialization of IP. Use of scientific publications, conferences and networking is added here as a form of UI link which can accompany all of the forms in the three above-mentioned levels of relational involvement. The authors then hint that the literature on relationships has been less consolidated than that of IP commercialization, even though the contribution of UI relationships to innovative activities in the commercial sector appear to have considerably exceeded that of IP transfer. The review concludes by proposing areas for further research on the search and match processes preceding UI relationships (with an open innovation perspective), as well as on the organization and management of UICs, which in turn are addressed at the levels of individual academics, organizations, and institutional level. On the individual level, the discussion is around the

alignment of incentive structures for academic researchers and industry staff to produce mutually beneficial results. On the organizational level, the implications of variety of contractual arrangements for their outputs are put forward for deeper investigation. Finally, at the institutional level, the authors call for further inquiry on the influence of national innovation systems and their prevailing institutions on the extent and forms of organizational arrangements of UICs.

Another systematic review paper which has tried to conceptualize UIC is the one by Ankrah and AL-Tabbaa (2015) who reviewed the UIC literature published between 1990 and 2014, and identified five key aspects for the theory of UIC, including the collaborations' forms, motivations, formation and activities, enablers and inhibitors, and outcomes. The authors present this conceptual process framework as a 'middle-range theory' alternative to the two established grand theories of 'interdependency' and 'interaction' on the genesis, development and maintenance of these relationships. The origin of such a categorization of grand theories on university-industry cooperation is to be found in Geisler's (1995) influential article, in which he purports that resource dependency motivates the initiation of UICs, while interaction theories explain their survivability. Ankrah and AL-Tabbaa, however, assert that their five-staged conceptual framework is more comprehensive by allowing for more orderly descriptions of particulars in UIC. One of the conclusions the authors make in terms of the areas in need of further investigation by researchers, then, is related to the intangible potential value of the UIC in the form of their impact on the learning experiences

of students affiliated to universities that have engaged with industry. As the authors indicate, this point is in line with the findings of Perkmann *et al*. (2013), which is another notable systematic review paper on the matter of subject.

Perkmann *et al*. (2013) and Perkmann *et al*. (2019) reviewed literature on academic engagement, the scope of which, as they clarify, makes engagement distinguished from teaching, research, and commercialization activities. The considered types of engagement (interactions) with external organizations in these two systematic review papers include collaborative research, contract research, consulting as well as informal activities like networking with practitioners. The authors of the 2013 review article had identified all the relevant research on the subject between the years 1980 and 2011, finding out that the number of relevant articles has increased significantly since 2005. In this paper, the authors categorize determinants of individual-level academic engagement into individual, organizational and institutional determinants. Here, the authors include the disciplinary factor as one of the institutional determinants of engagement and find from their literature review that there is a positive association between applied disciplines and academic engagement. Another element among the institutional determinants is the country-specific regulations and policy, which based on the authors' systematic review, has shown an ambiguous effect on the academics' external engagements. As to the individual and organizational determinants, while the authors find factors related to the earlier experiences and productivity of the academic individuals to be in

positive association with their external engagement, they report no organizational factor at the university for having shown a clear positive effect for the external engagements of academics.

The authors of the 2019 review article, then, conduct a systematic review of the literature from 2011 onwards, finding that the interest in publishing on the topic of academic engagement has increased to the extent that the publications' volume since 2011 has been larger than that of the multi-decade period covered by the previous article. Comparing the findings with the former systemic review article, the authors emphasize the relevance of, and need for research on aggregate department-level patterns of engagement, as well as the organization-level mechanisms supporting that. Furthermore, and in a close relation to the research on doctoral students' intersectoral collaborations, the authors point out that in the case of early stage researchers, academic engagement is less emphasized in comparison to the stress on publishing. Therefore, the authors point out, the process of external engagement by this group of academic researchers is specifically interesting to study, as such a topic is underexplored. Furthermore, their reviews show them that "[a]s before, it remains difficult to compare studies across countries and disciplines" (Perkmann *et al*., 2019, p. 4).

Rybnicek and Königsgrube (2019) article presents results from the authors' systematic literature review on university-industry collaborations with the aim of identifying the success factors of such relations. Referring to scholarly reports such as that of Perkmann *et al*. (2013), the authors of this review also point to the fact that over the last

two decades there has been an increased interest in university-industry cooperation, and limit their investigation to the papers written on the subject between 2000 and 2017. The success factors identified by the authors for the UICs are categorized as institutional, relationship, output, and (environment) framework factors, but the authors indicate that there are some other aspects of UICs which can moderate the influence of those success factors. These moderators include the scale of institutions, the phase of the collaboration project, the scientific discipline, and the organizational level of the collaboration. The authors point out that these moderators are in fact in need of further in-depth research.

The systematic review by Vick and Robertson (2018) focuses on the knowledge transfer between universities and industries in U.K., discussing Perkmann *et al*.'s (2013) four central measures of such collaborations including motivations, activities, barriers and outcomes. The authors reviewed the respective publications from 1995 to 2015, and categorize the existing studies on the aforementioned four aspects in two groups, namely the socio-political perspective and the contextual perspective, adding that the former group of studies have mainly discussed the motivations for collaborations, while the latter group have had collaboration activities and their outcomes at the centre of their investigations. Another finding is that the research on activities has mainly considered knowledge transfer as a unidirectional process, implying that the bidirectionality of the knowledge transfer activities needs further attention. Similar to Ankrah and AL-Tabbaa (2015) and Perkmann *et al*. (2013), when it comes to the outcomes of U-I links, Vick

and Robertson see a need for better definition of intangible or less tangible outcomes and their importance. Furthermore, and directly related to the topic of this dissertation, the authors point to the relative scarcity of studies exploring one specific discipline or sector and its particularities.

Another recent literature review on university-industry collaboration by Sjöö and Hellström (2019) identifies seven main factors stimulating collaborative innovation. These include resources, university organization, boundary-spanning functions, collaborative experience, culture, status centrality (R&D intensity and size) and environmental context (geographical and policy). The authors propose that these factors need not only to be scrutinized concerning their interrelations, but also based on their availability for intervention and amenability to change. Accordingly, the authors call for a deeper and a layered analysis of the factors stimulating the UI collaborative innovation, which would better inform the policy practice.

Literature on collaborative doctoral education and generic skills acquisition

The growing interest in university–industry research collaborations, which the above-mentioned systematic reviews reflect, has also become one of the emergent features of doctoral programmes in the developed economies over the recent past decades (Malfroy, 2011; Thune, 2009). Referring back to the university-business cooperation types identified by Galan-Muros and Plewa (2016), PhD education can be considered as an

arena for several types of UBCs such as student mobility, curriculum design, and R&D collaborations. The latter one, however, might be considered as the most common channel of collaborations, manifested mostly by joint supervision of PhD students and co-financing of PhD research projects. According to Assbring and Nuur (2017, p. 185), "[c]ollaborative doctoral education could be defined as arrangements in which the cost, supervision and research outcomes for the PhD project and/or programme are shared by industrial actors, funding bodies and academia."

Based on the university-industry relationships literature, Thune (2010) highlights the two factors of size and R&D intensity of firms as "two relevant independent variables that likely have an impact on how research collaborations are carried out" (p. 16). Similarly, in the assessment of Wallgren and Dahlgren (2005), companies' research and production environment significantly shapes the experience of doctoral students in terms of knowledge exchange modes as well as their own role in it.

Different roles can be assumed by doctoral students in such collaborations, as the level of engagement by either side of the relationship, and the goal sought by them can vary. Thune (2010) has extracted from the literature three roles for doctoral students in these relationships, including producers of knowledge in collaborative research projects, important channels for knowledge transfer between universities and firms, and vital actors in network configurations

between firms, government and universities. Similarly, Kunttu *et al*. (2018) refer to the role of collaborative doctoral students as boundary spanners (or boundary actors) for knowledge transfer between academia and industry through lowering the organizational and cultural barriers between them. Whatever the role is going to be, the legal status of doctoral researchers usually takes the form of employee of the university, employee of the firm, a combination of these, or fellowship from the university or a public research funding body. These collaborations have been manifested in various formats, and the extent to which it has become regulated and prevalent differs across countries with their varying levels of development in intersectoral research collaborations. These differences in collaboration formats largely define the role of the partners in the collaborative doctoral training. In Borrell-Damian *et al*.'s (2015) report prepared for the European University Association in which 13 European countries were represented, the most common type of contribution from the business partner in the collaborative doctoral schemes is the provision of funding. This element is closely followed by the issues of co-supervision, data provision and part- or full-time placement in the firm.

As mentioned in the first chapter, a very strong emphasis is given by the scholars of the innovation systems approach to the aspects of organizational as well as *individual learning* through interactive knowledge exchange between organizations and sectors. In line with this, the benefits of doctoral education involving intersectoral collaboration can be analyzed at the organizational (firm and university)

level as well as the level of individuals involved (here, doctoral researchers). University-industry collaborations organized through industrial PhD schools, for instance, have shown great benefits for the participating companies and universities (Gustavsson *et al*., 2016; Roolaht, 2015). Also, at the level of individual doctoral students, important advantages are perceived. These include bridging and integrating both the university and the business sector mindset for the doctoral candidate, the possibility to work in interdisciplinary areas, and developing transferable skills (Borrell-Damian *et al*., 2015). In the following parts of this section, first the literature dealing with the concept of transferable skills and its relation to doctoral education will be examined. Thereafter, the literature discussing variety of collaborative doctoral programmes, and the influence of disciplinary and national policy context on those programmes will be reviewed to substantiate the means by which the acquisition of transferable skills are pursued.

Literature on transferable (generic) skills acquisition and its relevance

The history of debates around *professional development* for doctoral students can be traced back to 1995 in the US, when the National Academies Committee on Science, Engineering and Public Policy suggested that doctoral students are not prepared sufficiently for professional works beyond research (Nerad, 2015). Similarly, in Australia the ministerial policy recommendations for knowledge and innovation (Kemp, 1999) called for improving the training of researchers in generic skills. In UK, the report by Roberts (2002) for the British

government argued about the need for training STEM fields' research students in transferable skills (Walsh *et al*., 2013). In line with these views, the European Commission's Berlin Communication (2003) also called for making the training of researchers in Europe of greater relevance for a wider variety of careers than in the past. It went on to suggest that doctoral programmes should enhance the employability of researchers by including in their training both core skills and wider employment-related skills. Kehm (2007) explains that following the next ministerial meetings (after the Berlin meeting in 2003) of European ministers responsible for higher education in Bergen in 2005, the European University Association (EUA) was commissioned to conduct the DOC-CAREERS I project between 2006 and 2009. The results of the project confirmed that in Europe, there exist challenges and barriers hindering university-industry cooperation, and that both sides of the cooperation share view on this. It also identified core components needed for collaborative doctoral education. This was followed by DOC-CAREERS II project running from 2009 to 2012, in part of which the authors report that from the viewpoint of the companies, the skills most in need of improvement by doctorate holders include entrepreneurial mindset, interdisciplinary knowledge, teamwork, and customer orientation (see Borrell-Damian *et al*., 2015, p. 50).

Another international survey of doctorate careers is the one conducted by OECD in collaboration with Eurostat and UNESCO, together which initiated the Careers of Doctorate Holders (CDH) project in 2004. In order to map their skills' use across the economy of the OECD member

countries. Using their data, Auriol (2010) showed that while the share of recent PhD graduates employed in the business sector varies significantly among the member countries, it had already reached to more than one-third in countries like Austria, Belgium and United States.

Beyond the policy-related reports, academic literature has also developed on the career of doctorate holders, picking up the issue of the change taking place in the sectoral patterns of their employment. Lee *et al*. (2010), for instance, pointed to the shift of the primary employment sector of science and engineering PhD holders in the UK from academia to industry, adding that their finding is in line with the trend in the U.S. based on the findings by Stephan (1996) and Stephan *et al*. (2004). Nevertheless, Lee *et al*. pointed to the international differences regarding the employment patterns of science and engineering PhD graduates – mentioning the opposite situation in France studied by Mangematin *et al*. (2000) – and add that "further research may look into the underlining institutional mechanisms that shape the differences". The study by Herrera and Nieto (2016) on the case of PhD graduates in Spain also finds that, similar to the case of France in Mangematin and colleagues' study, the majority of PhD graduates are still employed by the government or higher education sector.

The first publication discussing the nature and core of professional skills can be traced back to 1970s in UK. However, as Bennett *et al*. (1999, p. 75) explain, "[a] proliferation of lists of employers' skill demands appeared through the 1980's and early 1990's, but they did little to clarify the definitions of the skill labels used." In the U.S., those wider

employment-related skills are sometimes referred to as 'employability skills', as distinguished from academic skills and occupational (technical) skills (Lawrence, 2002). This distinction was similar to the one by Woodruffe (1993) who classified human resource competencies into two nuclei, including technical skills which are specific to a job, and generic skills which can be universal or transferable. Related to the employability skills, Watson (2010) found that in the U.S., graduates of engineering doctoral programmes lack interdisciplinary teamwork skills and specifically do not have enough grasp on the economic matters in industry. These wider employment-related skills are more commonly referred to as transferable skills in the European Commission and OECD documents. As per definition by the European Science Foundation (2010), transferable skills, in their broadest sense, are skills learned in one context that are useful in another. This definition had hitherto been debated by scholars of education studies. The paper by Bridges (1993) was one of the first to provide a clear scholarly debate around the concept of transferable skills. It distinguishes between transferable (generic) skills and cross-curricular (core) skills, arguing that the former group refers to applicability of skills across different social contexts, while the latter group implies application of skills across cognitive domains. Interpersonal communication, management skills, and group working skills are mentioned as examples of transferable skills. The cross-curricular skills are exemplified by numeracy, problem solving and information technology. Bridges continues, however, to argue that in order to make the notion of transferable skills intelligible, there is a need

for a theory of social domains (social contexts), similar to some classifications available for cognitive domains.

As another outstanding classification in the literature, Metcalfe *et al*., (2002) distinguish between the terms generic research skills, transferable skills and employment-related skills for referring to the postgraduate skills beyond the subject-specific ones. For these authors, generic skills refer to skills such as project management and academic writing, while team working exemplifies transferable skills, and employment-related skills are represented by interview techniques and career planning.

Hence, an important development emerging from the literature is related to the heterogeneity of transferable skills. And in fact, a delicate part of the discussions around transferable skills relates to their interrelatedness with the subject-specific skills associated with academic disciplinary areas. Not all the scholars agree on the nuances of this discussion. Zellner (2003), for instance, argues that the skills related to the capabilities to formulate, structure and solve a diverse range of problems are not specific to the knowledge area of candidates. Borrell-Damian et al.'s (2010) findings also shows that some of the transferable skills are perceived by academics to be so generic that they can be considered as independent of the field of knowledge with which doctorands are affiliated, such as social and communication skills, management, creative thinking, and team work. On the other hand, Kemp and Seagrave (1995) found that skills like report writing, oral presentation and group working are best developed when they are integrated as a component into

vocationally-oriented modules. This perception resonates with Bennett *et al*. (ibid) who argue for linking the provision of generic skills to frameworks of disciplinary and employment-related content knowledge.

In harmony with the above discussion, the literature around PhD education has also touched upon the competencies shared by PhDs across disciplines and context of doctoral education. For instance Durette *et al*., (2016), Mowbray and Halse (2010) and Cryer (1998) agree on some "core competencies" including disciplinary knowledge and skills, communications, project management, innovation management, cognitive abilities, problem solving, creativity, autonomy, perseverance, and capacity for adaptation. Nevertheless, findings by Jones (2009) demonstrate that skills such as critical thinking, problem solving, and communication are defined and taught differently across different academic disciplines. Therefore, Jones proposes a re-disciplined theorizing of generic skills, counting them as part of the *social practice* of the disciplines. In harmony with this line of argument, Huisman and Naidoo (2006) point explicitly to the need for being attentive to the difference that the factor of academic disciplines can make in terms of the implication of *Mode 2* knowledge generation (referring to the findings by Enders and De Weert, 2004), as well as for the learning experience of doctoral students from professional doctorates.

Given all the conceptualizations and classifications presented above in relation to generic (transferable) skills, a grouping of these skills proposed by González and Wagenaar (2003) stands out as one based on

which a more comprehensive and nuanced understanding of those skills can be achieved. These authors categorized generic skills into three groups: (i) *instrumental skills*, including cognitive, methodological, technological, and linguistic abilities; (ii) *interpersonal skills*, including social interaction and cooperation, and critical and ethical consciousness; and (iii) *systemic skills*, the ability to analyse the whole and understand how the parts work together, as well as how to combine and apply skills and knowledge to different situations. Adopting this classification facilitates taking a more detailed approach to the specifics of the generic skills, as it distinguishes between those which do have closer connection with the disciplinary skills (i.e. instrumental skills), with those which are more detached from field-specific traits (i.e. interpersonal skills) and those which rely on a combinatorial form of both types (i.e. systemic skills).

Literature on different types of collaborative doctorate

The afore-mentioned discussion around the shortcomings in doctorate holders' skills set has become a point of criticism for conventional PhD training. The graduates of conventional PhD programmes have sometimes been assessed as being ill informed about the employment outside academia, lacking key professional and managerial skills, and being too narrowly educated and trained (Nerad, 2004; Sursock & Smidt, 2010). Furthermore, the changing mode of generating knowledge from discoveries within the realm of individual disciplines to the transdisciplinary context of knowledge application, to which Gibbons *et*

al. (1994) referred as shifting from *Mode 1* to *Mode 2* knowledge production, has added further rationale to the need for changes in doctoral education. The previous section elaborated on the relevance of equipping doctoral candidates with transferable skills, and these types of skills, it has been argued, may best be acquired through training or through work experience (cf. Drummond *et al*., 1998).

Such a need for doctoral programmes adaptable to the needs of non-academic careers has been recognized firstly in the Anglo-Saxon and then in the European context (Huisman and Naidoo, 2006). Various types of professions-oriented and industrial collaborative doctorates have gradually emerged within the last century across different parts of the world. Harvard University has been given credit for awarding the first "professional doctorates" in 1921 in the field of Education (Bourner *et al*., 2001, cited by Jones, 2018). These professional doctorates have been replicated firstly in the Anglo-Saxon world, and have become distinguishable from conventional doctorates specifically through their emphasis on applied knowledge and defined workplace competencies, more explicit interdisciplinary approaches as well as alignments with industry, and a culminating project as alternatives to the dissertation (Servage, 2009). In the UK, industrial studentships and collaborative doctoral projects were promoted by the Economic and Social Research Council (ESRC) since the 1980s (Demeritt and Lees, 2005). At the latter half of 1980s and beginning of 1990s, degrees such as Doctor of Engineering (DEng) and Doctor of Business Administration (DBA) were established in the UK, forming the roots of such alternative doctorates in

Europe (Huisman and Naidoo, *ibid*). Subsequently, more doctorate models appeared in the UK. Huisman and Naidoo (*ibid*) came to a fivefold typology by broadening the doctorate types in the UK, which include the traditional PhD, the PhD by publication, the taught doctorate, the work-based or practice-based doctorate, and the professional doctorate. The latter two types, the authors explain, are to be considered as more professionally oriented, compared to the other three which are seen as more academically oriented types. Therefore, the practice-based and professional doctorates would be of more relevance to the theme of alternative doctorates. More recently, however, Boud and Tennant (2006) have argued that in order to meet the need for new knowledge workers to support innovation and economic development, doctoral education needs to look beyond the traditional PhD as well as designated (named) professional doctorates. In this regard, these last authors refer to examples of generic professional doctorate and doctorate by project. Within the generic professional doctorate, the doctoral program is neither totally discipline-focused nor fully located within a particular professional group. The doctorate by project is seen as a logical extension of professional doctorate and is focused on dealing with specific problems at workplace. The evaluation in both cases is based on exegetical written works and, in case of the project-based doctorate, an artefact produced through the project, rather than a conventional academic thesis.

Similarly, Jones (2018) has studied the contemporary trends in professional doctorates and has distinguished between the first

generation and new generation models. As he explains, the former generation were modelled on the research Master's degree, i.e. included an initial component of coursework and a last one based on research, relied more on individualized supervision, and served primarily academic purposes. The new generation, however, relied more on partnership with professional organizations, and served primarily industry through its greater emphasis on applied research. Netherlands is an exemplar country which has opted for the new generation professional doctorates, with professional doctorate in engineering (PDEng) being a well-established postgraduate degree in the country. What distinguishes this programme from the first generation professional doctorates is that the candidates also get opportunity for education and training in skills beyond those very specific to the profession, therefore better fit for providing training on generic skills.

Industrial collaborative doctoral programmes are another important form of alternative doctorates which, even though not designated for training doctoral candidates towards a very specific profession but entail a relatively intense practice-oriented doctoral education. Similar to the case of professional doctorates, industrial doctorates have also taken slightly different forms in different countries. Kitagawa (2014) explains that while in the US and Australia, *centre format* of collaborative doctoral programmes have had a rather long history, and in the UK, the co-existence of the *centre format* and *non-centre format* has been more obvious since the early 1990s, in continental Europe, *non-centre format* has prevailed. The author specifically mentions the establishment of

industrial PhD programmes in Denmark and France as examples of the latter format.

All in all, even by the turn of the millennia, professional doctorates were still seen as a rather new trend in doctoral education in countries such as the US, the UK, the Netherlands and Austria (Kehm, 2004). Nevertheless, Enders (2005) refers to this trend of increasing spread of alternative doctorates as the paradigm shift of doctoral training in Europe from the traditional so-called Humboldtian model towards the so-called professional model. In line with this trend, further alternative models of doctoral education have emerged during the last two decades. Discussing new forms of doctoral education in the European Higher Education Area, Kehm (2009) identified eight models of doctorate in Europe - which are mostly progressed in the UK. These include *the research doctorate*, *the professional doctorate*, *the taught doctorate*, *PhD by published work*, *the practice-based doctorate*, *the "new route" doctorate*, *two models of the joint doctorate*, and *the industrial doctorate*. Later, Bao *et al*. (2018) added *cooperative doctorate* to this list but maintained that the main differentiation is "between a research doctorate and a professional doctorate" (p. 530). The main features of the above-mentioned doctorate models can be outlined as:

- *The research doctorate*: this is a conventional model in which producing a dissertation as an original contribution to the research field is the key element. This model can be found in the

form of both structured programmes and a master-apprentice framework.

- *The professional doctorate*: in this model the programmes are restricted to specific professional subjects like medicine and healthcare, engineering, business administration, education, etc. The title of the awarded degree usually indicates the professional field (e.g. DBA, PDEng, EdD) and the research skills pursued are usually defined towards the needs of the professional context. The dissertation aims more at contributing applied knowledge to the professional domain, and having a related professional background is often expected from the applicants of the programmes. Following the example of UK, professional doctorates are more widely found in countries like the Netherlands, Austria, Belgium, and France.
- *The taught doctorate*: inclusion of a substantial amount of course work in the doctoral programme is the key feature in this model. A research project is another component of the programme in this model, and it is graded like the courses after an oral examination consisting of the report of the research component.
- *PhD by published work*: the main feature in this model is combining several scientific articles published (or intended for being published) in peer-reviewed scientific journals. This model originated in Germany as 'cumulative dissertation' but has spread to other parts of Europe like the Benelux and Scandinavian countries as well. A programme of additional

studies like course works are included in the programme in most countries implementing this model.

- *The practice-based doctorate*: this model is used mainly in UK and Australia within the fields of arts and design, and constitutes of course works as well as a work of art instead of the dissertation, which is deemed as new knowledge through practice.
- *The new route doctorate (integrated doctorate)*: this model is also developed in the UK, and its programme consists of three integrated elements, namely a taught component on subject specialisation and methods, another taught component on transferable skills, and the dissertation. The model follows the American model of integrated postgraduate in which the Master's and doctoral level studies are combined in terms of the course work.
- *Two models of the joint doctorate*: in this model two or more universities, which may be or not be from the same country, offer a joint curriculum for the taught component. The funding, mobility and quality assurance are agreed upon by the involved institutions, as well as the possible joint supervision and the certification. 'European doctorate' is deemed as a particular variant of this model but is still under discussion rather than being on offer.
- *The cooperative doctorate*: this model is characterized by joint supervision of a doctoral candidate by supervisors from a

university and a university of applied sciences. While the research topic is often decided upon between the candidate and the supervisor from university of applied sciences, the course work is typically conducted at a university, and the degree is awarded by the latter institution.

- *The industrial doctorate*: this model is characterized mainly by a research on a particular problem defined by a company that hires and fully or partly funds the doctoral education of the candidate. The research has an applied nature and is supervised on the company's side, while the taught elements and theoretical parts of the research are supervised by the academic supervisor. This model is mostly used within the field of engineering, but other disciplines can also benefit from this type of programme whenever it fits the purposes of the industry. Industrial PhD specifically gained traction in Scandinavian countries as well as France.

Given the long history of awarding doctoral degrees in Europe, the introduction of these new modes of conducting doctoral education has not been an easy task. In this respect, Huisman and Naidoo (2006) bring up the argument that since the doctorate is "one of the few remnants of the core of the classical university", changing its structure and culture has not been easy, specifically since such changes need to be accepted by traditional universities too. Therefore, Huisman and Naidoo argue that both *adapting* the traditional PhD to the required changes and *looking beyond* traditional PhD is needed. The adaptation path has also

already taken root in some countries, such as the Industrial PhD programmes in Scandinavian countries. As mentioned, within such programmes, doctoral candidates work on a project defined by a company in cooperation with the candidate's university. The university is usually expected to offer courses targeting business-related skills for the candidates in these programmes. Also, the supervision task is often shared by the university and the industrial partner who also often (co)funds the doctoral education of the candidates through a salary.

Huisman and Naidoo (*ibid*) specifically name the Netherlands and Sweden as two countries beyond the Anglo-Saxon world in which the professionally oriented doctorates have taken root. In Sweden, Industrial PhD is also called Organizational PhD, and represents the most well-known form of collaborative PhD. Industrial PhD programmes were first established in Denmark in 1988, when the Industrial Research Programme, established in the 1970s, was repurposed to focus on doctoral education (Kihlander *et al*., 2011). Subsequently, the Industrial PhD model also appeared in the rest of Scandinavia, but different variants have also appeared in some other European countries as well.

In harmony with their intended purposes, scholars have discussed that industrial doctorate programmes have succeeded in helping candidates to develop transferable skills (Wardennar *et al*., 2014; Roach and Sauermann, 2010; Roberts, 2018; Grimm, 2018). Nevertheless, it needs to be mentioned that not all the scholars have come to the same conclusions regarding the benefits of this type of collaborative doctorate.

Kollerud (2012), for instance, provides a contradictory evidence from Norway. His study of collaborative doctorates in the Norwegian context showed no significant relationship between having been in contact with industry and acquiring generic skills. The author argues that it is the research discipline and work experience that have plausible impact on learning outcomes and skills acquisition in doctoral education.

Grimm (2018) has examined the value of industrial PhD programmes within the field of engineering as experienced by university and industry stakeholders in Germany, and has discussed what needs to be adjusted for these programmes to be successful. One overall finding is that unlike the other types of university-industry research collaborations which are usually perceived mutually beneficial by both sides, in case of industrial PhD, one side of the collaboration is often sceptical about the concept of the collaborative programme. Nevertheless, Grimm finds the acquisition of context-related and practice-relevant skills as an issue which still motivates both sides to engage in industrial PhD Programmes.

These examples point to the importance and relevance of taking into consideration the national differences, when assessing the experiences of doctoral students from participation in collaborative and professional doctorate programmes. Nerad (2015) shows that definition of professional development for doctoral students differs by country, which is rooted in historical development of the process and structure of educating doctoral students. Pointing to the distinction between the tradition of structured doctoral programmes in the U.S. versus

unstructured (master-apprentice) model in Germany, Nerad explains that such a distinction has become blurred in the European context since the turn of the millennia. More and more, "structured" elements such as course works have been introduced to doctoral education in European countries, including enhanced focus on training the candidates in transferable skills.

Further, as a consequence of uptake of New Public Management within higher education system of many European countries, the importance of research collaborations with industry have increased, which is partly related to securing sources of external funding. Hence, the heightened attention to the "third mission" activities in the form of engagement with industry has also touched on the issue of doctoral education. Discussing the impact of the third mission of universities on doctoral education, Santos (2016) argues that "changes in structure of university system condition and shape the nature and structure of doctoral programs" (p. 108). She mentions professional doctorate in Australia and UK, and an example of collaborative doctorate in Portugal known as Doctoral Programmes in Business Environment, both of which aim to respond to the needs of the knowledge economy. Nevertheless, the relative scarcity of large and R&D-intensive companies in Portugal are highlighted in the paper, in addition to the fact that large majority of doctorates continue their career in the higher education sector. The key point here is that the intensity of intersectoral relations between universities and industry in the country has important implications for the prevalence and structure of collaborative doctorates.

Relatedly, in a study that reflects on the influence of Triple Helix configurations on doctoral education, Assbring and Nuur (2017) highlight the experience of industrial PhD schools in Sweden, elaborating on their organization as well as their benefits for industry. The authors identify four criteria in the organization of university-industry collaboration, derived from the *industry relevance* dimension. These include co-financing, joint supervision, joint formulation of research project, and structured placement. The authors argue that the outcomes from collaborative doctorate are highly dependent on different modes of organizing these four dimensions.

Accordingly, it can be hypothesized that the industrial relevance of doctoral education, in terms of equipping doctoral students with professional and transferable skills is subject to the above-mentioned dimensions of organizing the collaborative doctorate programmes, which in turn are partly influenced by the specifics of national context such as systematic university-industry interactions. As indicated, different types of professions-oriented and industrial collaborative doctoral programmes have emerged in Europe, especially during the last three decades. CIFRE (2010) provides a useful classification of the integration level of "company partnership" in doctoral education in Europe. At the level of *full (complete) integration*, Sweden and Denmark are mentioned, with Industrial PhD programme representing a mode of collaboration in which the doctoral candidate is employed and co-supervised by the company. At the level of *moderate integration*, countries like Germany, UK, Ireland and Portugal are mentioned, in

which case the collaborative programmes include co-supervision but the duration of the candidates' "internship" within the company varies between 3 to 18 months. Finally, in countries like Italy and Switzerland, the collaborative doctoral programmes often do not include a direct partnership with a company, but the candidates get the opportunity to deal with concrete sector-specific issues (e.g. in biotechnology, biology, molecular medicine, etc.).

In conclusion, it can be argued that the literature on *collaborative doctorates in Europe* and *transferable skills acquisition*, both suggest an understanding of the collaborative doctorate in which the "disciplinary factor" exerts a crucial influence on the occurrence of the intersectoral collaboration, and the learning experience based on that. This is evident from the fact that:

1) the literature on transferable skills acquisition points to the high relevance of discussions around distinguishing between the types of skills which are more intertwined with disciplinary learning and those which are not. This issue becomes of further prominence in light of the variety of collaborative and professions-oriented doctoral programmes, within which there exist differing levels of integration with the practice environment, as well as relatively divergent levels of professions-specific training with strict disciplinary designations of the doctoral programme.

2) the literature on collaborative doctorates points to the high relevance of disciplinary specifics in the emerging of alternative doctorate programmes which have aimed at professional development for doctorands. At the same time, this stream of literature highlights the variety that the national specifics in terms of intersectoral collaborations and doctoral education traditions generate regarding the prevalent types of doctoral programmes and their various dimensions. Professional doctorate and industrial PhD stand out as more frequently discussed types of collaborative doctorate in the literature and exhibit a relatively more complete integration of practice-oriented approaches to doctoral education across a wider range of disciplines. While the professional doctorate represents a more radical alternative to traditional PhD due to its discipline-specific *designated* programmes, industrial PhD represents an *adaptation* of the traditional PhD to the necessities of the labour market for doctoral graduates without as strict placement (enrollment) preconditions as is the case of professional doctorates. The co-financing, co-supervision, and joint formulation of research project are common dimensions between the two programmes, but their nuances can vary based on the national adaptations of the two approaches.

3 Theory and research paradigm

In this section the aim is to establish both theoretical and metatheoretical underpinnings of the dissertation, based on the conceptual implications from the research questions, interpreted in juxtaposition with the conceptual shortcomings of the past research. As put forward by Talcott Parsons (1979), the prominent scholar of the general social systems theory, "[…] *theory not only has no scientific relevance if it is not adequately integrated with knowledge of empirical fact but at the same time theory must be adequately grounded in what more than any other term we call a philosophical position*" (p. 5). In agreement with Parsons who finds the term "frame of reference" as most appropriate term to characterize the conceptualizations at the metatheoretical level (Parsons, *ibid,* p. 15), the aim is here to establish the link between the theoretical choice with the references it makes to the ontological and epistemological layers of the inquiry.

In the following, first the implications from the research questions for the theoretical development are outlined. Then, those implications are juxtaposed with the findings from the past research, based on which the next part elaborates about the relevance of the chosen theoretical grounding. This is then positioned within the metatheoretical approach in order to establish the coherence of the theoretical and empirical parts of the inquiry in this dissertation.

Implications from the research questions

The three main research questions of this dissertation, as presented on page 12, represent a set of *embedded questions*. This means that the first question, which asks about the prevalence of collaborative doctorates across academic departments, provides a precursor for the second question, which in turn, asks about the learning experience of doctoral researchers from collaborative doctorates. Accordingly, a *conjecture* links these two questions, that is *engagement in collaborative doctorates contributes to the learning of transferable skills*. This conjecture is largely backed by the scholarly findings in the literature (see the previous section on collaborative doctorates and generic skills acquisition). Consequently, the third research question draws on the mentioned conjecture to ask about policy recommendations which can be derived from the answers to the former two questions. Hence, the conceptual underpinnings of the first research question arguably determine the overall theoretical framework of this dissertation. In other words, the first question constitutes the *core question* of the research, the answer to which has significant consequences for the pursuit of an answer to the next questions. Nevertheless, as it was discussed in the previous section on generic skills, the second research question also embeds an element of inquiry on the importance of disciplinary specifics due to the hypothesized interrelation between some of the generic skills and disciplinary learning. When it comes to the conceptualization of the first research question, then, it can be argued that this question seeks a primacy for the factor of academic disciplines in the comprehension and

analysis of doctoral researchers' external engagements. This is because the question highlights possible differences across academic departments in terms of harboring various levels of opportunity for collaborative doctorates.

Implications from the past research

The review of the past literature on the subject of UICs, and collaborative doctorates as a specific form of UICs, points to the high relevance of disciplines-centered study of the phenomenon, in harmony with the implications from the core research question. Seen from the broader perspective of UICs literature, collaborative doctorates fit within what Perkmann and Walsh (2007) categorize as mobility (transfer) of human resources between universities and industry. These authors explain that *mobility* forms such as companies sponsoring PhD studentships can be seen as intrinsic to high level UI relationships if it is part of specific collaborative projects. Nevertheless, they continue to suggest that "*[…] human mobility aimed at transferring generic skills, such as graduates seeking work in industry, is part of a more infrastructural role of universities and is therefore not classified under the relationship category*" (p. 263). Despite this point, when discussing the high-level UI relationships, the issue of implications of academic fields for the UI linking mechanisms is highlighted by the authors. They emphasize that it is not enough to make distinction between science-intensive versus other sectors in making distinction about the prevalent linking mechanisms (i.e. collaborative research, contract research, consulting

etc.). Instead, they conclude from overview of a number of surveys that a more fitting distinguishing factor is the industrial sectors seen through the lens of their corresponding academic fields (e.g. science-based versus engineering fields).

Also, as indicated in the section on past research, the systematic reviews by Ankrah and AL-Tabbaa (2015) and Perkmann *et al*. (2013) emphasized the need for further research on the learning experiences of students from engagement in UICs. While Ankrah and AL-Tabbaa do not refer to the disciplinary factor, Perkmann *et al*. (2013) clearly highlight it, based on their literature review, as one of the determinants of academics' external engagement. As mentioned before, these last authors also refer to country-specific policies and regulations, as well as organizational factors, in addition to individual factors as the other determinants of external engagement. Paper II in this dissertation uses this classification in order to discuss these factors in their most relevant form for collaborative doctoral education. This paper clarifies that the factors other than the disciplinary factor are classified as contextual factors in this dissertation, while the disciplinary factor, based on reasons which will be explained in the next part, is singled out as the "real" underlying mechanism.

Then, Perkmann *et al*.'s (2019) updated review revealed that department-level patterns of academics' engagement with industry are still underexplored in the literature. This is while the same paper also advocated for further attention to the early stage researchers' external

engagements. Also the systematic reviews by Rybnicek and Königsgrube (2019) and Vick and Robertson (2018) reveal that they share the point on the need for further research with explicit focus on disciplinary specifics of the UICs. Rybnicek and Königsgrube mention scientific discipline as one of the factors whose moderating effect on UICs needs more in-depth research.

Finally, even though Sjöö and Hellström (2019) do not make any reference to the disciplinary factor in their review, their emphasis on the need for a *layered analysis* of UI collaborative innovations based on the amenability of the factors to change, makes a direct ontological sense to the approach taken in this thesis. This is because the disciplinary factor is seen, as indicated before, as harboring a "real" underlying mechanism more deeply embedded in the occurrence of collaborative doctorates than the other "contextual" factors such as regulatory and organizational ones.

Viewed via the lens of literature on doctoral researchers' intersectoral engagements and its learning outcomes, then, the above-mentioned fundamental role of disciplinary specifics is corroborated. As indicated in the previous section, the intensity of the debates around typology of the graduate skills has specifically been high around their interrelations with disciplinary specifics. What is strikingly relevant to the current research, is that Jones (2009) who advocated for a re-disciplined understanding of generic skills, even refers to this as "social practice of disciplines", which is an apparent use of ATT terminology and concepts - which will be introduced in the following. In other words, doctorate

skills' debate seems to be also amenable to the theories on essentiality of disciplinary specifics, like the issue of intersectoral engagement. The aforementioned usage of categorization of transferable skills proposed by González and Wagenaar (2003) in this dissertation not only allows for a nuanced understanding of transferable skills with regards to their sensitivity to disciplinary influence, but also makes space for reconciling the two distinct categories (instrumental and interpersonal skills) by considering a third category as systemic skills which allows for the combination of two views. This will leave more possibilities for theory-building based on the empirical findings of the research.

Also, taking the literature on collaborative doctorates into consideration, the fact that these alternative doctorate programmes are often (e.g. in the case of industrial doctorate) or always (in the case of professional doctorate) used by specific academic disciplines, puts further emphasis on the *generative* role of disciplines on the emerging of collaborative doctorate models. What this stream of literature brings further under spotlight is the difference that national regulations make for the types of alternative and collaborative doctorates. As indicated in the previous section, relatively different types of professionally oriented doctorates have appeared in Europe, mainly in the form of professional and industrial doctorates. These programmes put different levels of emphasis, in different forms, on training of doctoral candidates on transferable skills. Nevertheless, the fact that these programmes are replicated more or less similarly across countries which adopt them,

indicates the generative power of the disciplinary factor on the emerging of collaborative doctorate schemes.

In light of the foregoing, the factor of *disciplinary specifics* and its degree of potency in affecting the vastness of opportunities for intersectoral engagement of doctoral students gains a central position in the conceptual and analytical framework of the current research. Neither from a logical point of view, nor from the literature's consensus, the relations between disciplines, intersectoral engagement and the learning of generic skills represent a linear causality, in the sense that the former is capable of *predicting* the latter. As indicated above, the contextual factors related to country-specific regulations and universities' policies on intersectoral collaborations and collaborative doctorate have an important role in the actualization of the generative role of disciplines.

Hence, in agreement with what Hedström and Wennberg (2017) refer to as *situational mechanisms* shaping an actor's opportunities, goals, beliefs, etc., the disciplinary factor needs to be seen as an underlying but partial mechanism which shape doctorands' opportunities through their embeddedness in the environment of an specific academic department. Then, contextual (regulatory and organizational) mechanisms act as *action-formation mechanisms*, which in combination with the situational mechanism of disciplinary (departmental) affiliation, result in the learning behavior of doctoral researchers. Hedström and Wennberg bring up these mechanisms, it should be noted, as an alternative approach to economics-inspired frameworks in identification of causality within the

academic fields of organization and innovation studies. As these authors argue, despite the usefulness of such instrumental-variable techniques for methodological development in these academic fields, "their potential for theoretical generalization and replication remains very limited" (p. 3).

There exist important findings in the literature on academics' external engagements which have implications consistent with the above-mentioned conceptualization. Notably, Pinheiro *et al*. (2012) debated patterns of academics' external engagement in light of knowledge structure grouping of academic departments. Their analysis is based on categorization of disciplinary cultures proposed by Becher (1994). From their findings, the authors came to the conclusion that while knowledge domains do explain some general patterns of external engagement by academics, the influence of some locally rooted (contextual) aspects of academic profession on those patterns should not be neglected. In another argument in line with this latter point, Lee *et al*. (2010) also expressed the need for more attention to the contextual factors in shaping the career pattern of doctorate holders, to complement the 'academic factors' which had hitherto been the main focus of the literature for that matter. The next part demonstrates how the ATT thesis fits for the purpose of theorizing the confluence of disciplinary and contextual factors on the prevalence of, and experience from collaborative doctorates.

Theoretical underpinning of the research

The disciplinary categorization used by Becher (*ibid*) constitutes the core of a prominent thesis within higher education research known as the Academic Tribe and Territories (ATT) thesis. This thesis states, in its initial edition, that the knowledge structures of disciplines (the academic territories) strongly condition or even determine the research practices of academics (the academic tribes). These knowledge structures, also known by the ATT scholars as the epistemological core of disciplines, have been theorized as having cognitive and social dimensions. While the cognitive dimension characterizes the scientific field itself, the social dimension typifies the interaction levels of academics within each category. Conforming to the classification made earlier by Biglan (1973), Becher (1994) categorized the disciplines into four groups, namely hard-pure (natural sciences), hard-applied (science-based professions), soft-pure (humanities and social sciences) and soft-applied (social professions) disciplines.

Since the interdependence between the learning of disciplinary skills and transferable skills constitutes an important question in the current research, it is noteworthy to discuss what characterizes the learning goals of the four above-mentioned disciplinary areas. The cognitive purposes of these disciplinary areas differ considerably (White and Liccardi, 2006). For the hard-pure disciplines, the main cognitive purposes include logical reasoning, and testing of ideas and theories in a linear from of argumentation. For the hard-applied disciplines the key cognitive

purposes include problem-solving and practical application of existing knowledge. Soft-pure disciplines emphasize creativity in thinking and developing intellectual ideas, while soft-applied disciplines aim to improve professional practice through intellectual reflection and learning. Accordingly, the ATT thesis can imply for the discussion on the acquisition of transferable skills, that different disciplinary groups have differing potentials for the improvement of those skills through intersectoral engagement and learning. Consequently, the adoption of the ATT thesis as the theoretical underpinning in the current research finds relevance both in finding out whether the intersectoral collaboration opportunities are amenable to the specifics of the disciplinary categories, and in providing explanations for the acquisition of generic skills in relation to the above-mentioned discipline-specific cognitive skills.

Furthermore, as will be explained here, the adoption of the ATT thesis itself helps to develop an alternative hypothesis regarding the significance of disciplinary specifics, which corresponds to an important aspect of learning in higher education. When Haggis (2009) reviewed the research literature on student learning in higher education, he found that it primarily has rested on the cognitive perspective of learning, and argued that *interactional processes* that emerge over time and across learning processes have been downplayed in the research. In other words, the aspects of learning related to the environment of the learners (as opposed to their inner traits) have received less attention in higher education research. Fortunately, however, the hypothetical basis of the

ATT thesis, and the development of two antithetical positions around it over time, helps to avoid the one-sided attention on the cognitive (discipline-specific) reading of the thesis.

In fact, over the decades after the original book on the ATT thesis by Becher (1989), the initial essentialist view which attached high importance to the cognitive dimension of disciplines evolved into a weak essentialist view, better known as the social practice view, elaborated in the book by Trowler *et al*. (2012). This meant that the latter edition of the thesis put more emphasis on other impactful structures emanating from the context in which the academic practices are conducted. The fact that these two extreme views represent positions with different level of emphasis on the role of knowledge structure versus context of knowledge practice, provides a very fitting theoretical framework to the conduct of the analytical part of the current research. Accordingly, while the essentialist edition of ATT thesis would hypothesize academic disciplines as a factor strongly patterning the intersectoral engagements of doctoral researchers, the social practice edition would imply a contextually varied pattern for that matter.

The foregoing elucidation also helps in deciding the research paradigm underpinning the approach to research data analysis. The choice of research paradigm is influenced by three factors, namely the researcher's assumptions about the nature of reality and knowledge, the theoretical framework and existing literature, as well as the researcher's value system (Chilisa and Kawulich, 2012). Taking into account the

conceptual underpinnings of the (original) ATT thesis and the aforementioned role considered for academic disciplines as situational mechanism underpinning the intersectoral collaborations, the epistemological core of disciplines can be perceived, at least hypothetically, as a factor deeply embedded in the occurrence of such collaborations. Nevertheless, the latter edition of the ATT thesis puts this position exposed to a possible correction by advocating for a weak essentialist view on the influence of disciplines. This puts the theoretical framework in a "middle-range theories" position, based on which the ATT thesis functions as a *working hypothesis* to guide the empirical research (Merton, 1968). Such a position is also reinforced by the dichotomous fronts in the literature around the possibility of interrelatedness of disciplines and the learning of generic skills. In other words, the purpose of the research would become *theory-building* rather than *theory-testing*. Table 1 outlines the application of ATT thesis in each of the papers in this dissertation.

Article No.	Use of ATT thesis in the articles of this dissertation
I	Not used – this article uses an inductive methodology in describing the issue of doctorate skills mismatch with industry expectations across two different contexts.
II	This article is a conceptual paper, in which the role of ATT thesis is explained as providing the "proto-theory" within the overall critical realist approach underlying the dissertation. This means that ATT thesis is used as a theory which the empirical research seeks to improve. Furthermore, it is explained in the paper that the ATT thesis' two alternative editions (essentialist vs. social practice view) provide the two initial "competing mechanisms" in explanation of the degree of essentiality of disciplinary groups for the intersectoral collaborations of doctoral researchers.
III	This article uses a deductive methodology in order to investigate whether each of the alternative editions of the ATT thesis can explain the patterns of intersectoral collaborations among doctoral researchers from 4 European universities. The article finds that there exists discrepancy between disciplinary groups in terms of their compliance with the implications of the essentialist versus social practice view within the ATT thesis. This result implies that the degree to which disciplinary specifics are consistent in explaining the patterns of collaborative doctorates across country and university contexts, varies across the four disciplinary groups in the ATT thesis.
IV	This article uses an abductive methodology to identify the way contextual and disciplinary mechanisms confluence the experience of doctoral researchers from participation in collaborative doctorates in two different contexts, thereby retroducing the best rational explanation (improved theory) for the observed empirics. Combined with the findings from the paper III, an improved reading of the proto-theory (the ATT thesis) is achieved as a result of the analyses in this paper (as theory-building is the goal of CR-based research). The results indicate that in case of hard-applied disciplines, the weak essentialist reading of the ATT thesis can better explain the collaborative doctorate experience of doctoral researchers in terms of perceived acquisition of transferable skills.

Table 1 - The application of ATT thesis as the theoretical underpinning in the dissertation articles.

Metatheoretical underpinning of the research

Corresponding to the theoretical condition explained above and referring back to the arguments put forward by Hedström and Wennberg (2017), the current research evades from adopting a positivist meta-theoretical approach, replacing it with a post-positivist one. Under a post-positivist paradigm, observations are deemed as theory-laden and influenced by the observer's worldview. Based on this, it is acknowledged that observations may include error, and theories can be modified. In line with this, in the current research the relation between disciplinary specifics and intersectoral collaboration during doctoral education as well as the learning of generic skills, is hypothesized using the ATT thesis. Nevertheless, from this viewpoint, the disciplinary affiliation does not cause the intersectoral collaboration, but is an integral part of the *emerging of the collaboration* due to the practical implications of disciplines' epistemological core. This view gives intersectoral collaboration, as the phenomenon of interest, an *ontological depth* in terms of the reality being studied, an approach which is characteristic of *critical realism*. As a post-positivist paradigm, critical realism is deemed as stronger than many other forms of post-positivism (Cruickshank, 2012).

Critical realists go beyond what they deem as "naïve realism" of empiricists – the belief that the reality can be sensed (observed) by researchers in its totality – by resorting to a new ontology of reality, and argue that the natural and social sciences need to be based on a coherent

definition of reality. The concept of *mechanisms* is central to critical realist ontology. Mechanisms can exist beneath the empirical surface and be not directly observable. Based on observed phenomena the task will then be to find the underlying mechanisms that produce the phenomena and to "understand the interplay between them and how they shape the outcome" (Danermark 2002, p. 59). Context thus determines how a fundamental mechanism is empirically manifest. The ability of mechanisms to combine to create something new is called *emergence* (Danermark, 2002; Bhaskar, 1998a). Accordingly, the aim in the current research is to explain the interplay of disciplinary and contextual mechanisms, which lead to the emergence of established collaborative doctorate forms and practices supporting the acquisition of generic skills by doctorands. An important consideration here relates to the issue of causality, which differs within the CR paradigm from the positivist understanding of causality, and the next section includes elaborations on this issue.

Another key tenet in CR is the view that social structures precede human agency, but that they are also reproduced by agential actions (Archer, 1995). This is a crucial theme concerning the emergence of academic practices of individuals (doctorands) based on disciplinary or social practices (respectively according to the former and latter edition of ATT). Hence, the next sections also elaborate on the structure-agency relations using a critical realist conception of causal mechanisms. This will have important implications for the way the empirical research results are interpreted.

Critical realism versus other paradigms

Philosophy of science has historically seen three broad positions developed. These include *classical empiricism*, *transcendental idealism*, and *transcendental realism* (Bhaskar, 2008). While in classical empiricism the objects of knowledge are phenomena constituting natural facts, in transcendental idealism they are human mind's constructs imposed upon phenomena, and in transcendental realism they are real (but not necessarily observable) mechanisms that generate phenomena. While classical empiricism is most commonly represented by David Hume's experimentalism, transcendental idealism is best known by Immanuel Kant's synthesis of rationalism and empiricism, and transcendental realism is foremost associated with Roy Bhaskar's critic of both positivist (empiricist) and postmodern accounts of scientific enquiry, leading him to propose critical realism.

As another prominent figure in the tradition of critical realism, Sayer (2000) distinguishes realism, within the philosophy of natural science, from empiricism and relativism; and within the philosophy of social science, from scientism and interpretivism. Regarding the latter distinction, which is the main concern here, he explains *"[…] in the philosophy and methodology of social science, critical realism provides an alternative to both hopes of a law-finding science of society modelled on natural science methodology and the anti-naturalist or interpretivist reductions of social science to the interpretation of meaning*." (Sayer, *ibid*, p. 2).

Tikly (2015) has elaborated on the need for going beyond both empiricism and interpretivism in researching learning, arguing that critical realism helps to reflect the laminated view of learning. This means that the fact that individuals' learning is nested within other learning sub-systems, such as interorganizational linkages and national educational policies and discourses, is better reflected using the CR approach. Based on Tikly's (*ibid*) arguments, the merits and pitfalls of each of the three metatheoretical approaches can be summarized as:

- *Empiricism*: this metatheoretical approach assumes that positivist social research can discover generalizable laws and reliable predictions, often merely based on statistical models deemed as reflecting the reality. Rather than supporting a specific theory of learning, empiricism rests upon a behaviorist understanding of biological / cognitive response of learners to environmental conditions. Empiricism's ability to provide rules for what is logically valid conclusions based on given premises is considered as its key strength.

  Conflating the reality with empirical observations constitutes the core critique that CR advocates about empiricism. In this sense, it is argued that empiricism's emphasis on the most robust way of measuring events or phenomena, compromises achieving a deep understanding of mechanisms that give rise to the observed events or phenomena. Furthermore, CR argues that social systems are open systems, meaning that the effect of individual mechanisms cannot be isolated, making predictions based on

empiricist approaches less valid. Instead, CR emphasizes understanding and explaining the interplay of structure and agency at each specific context.

Another important critique against empiricism in social sciences relates to its supposed objectivity of empirical research. This becomes specifically problematic taking into account the role of agents' subjective perceptions about their learning experience, which is the source of empirical data in the current research.

- *Interpretivism*: this metatheoretical approach implies that social reality is relative and context dependent, and subject to human perceptions. The ability to reflect the situatedness of learning and the emphasis on the agents' (learners') perceptions, values and experiences comprise a notable strength of this approach. The potency of this approach in providing emancipatory perspectives based on anti-foundational assumptions is also often highlighted as one of its main merits.

  Nevertheless, interpretivism is also faced with important critiques. First, there exist a fundamental issue with interpretivism's denial of existence of any external (objective) reality independent of human mind. CR advocates hold the view that, despite fallibility of the knowledge gained about the reality, its existence independent of agents' knowledge cannot be denied. In addition, the sole emphasis on inductive modes of reasoning (like grounded theory) which is pervasive in interpretivism, is deemed as risking oversimplification of the reality about

phenomenon based on limited data. This also links to the issue of getting relevance in view of policy makers, as interpretation is seen here as receiving priority over causality. More concretely, concerning the topic of learning, the over-emphasis put on subjective cultural aspects of learning, it can be argued, fails to pay adequate attention on cognitive dimension which is often seen as a necessary part of understanding the mechanisms shaping the learning experience.

- *Critical realism*: the advocates of this metatheoretical approach have argued that the two aforementioned metatheoretical approaches are not paying adequate attention to the ontology of reality being researched. Critical realists distinguish between what they consider as relatively enduring causal structures and mechanisms, called intransitive domain, and our constructions and theories about that reality, called transitive domain. In a nutshell, the aim of social sciences research is to find the most rational explanation about the intransitive domain based on observations feeding the insights about the transitive domain of reality. This deeper understanding of reality can be considered as the key strength of the CR approach, and it has gained traction in the field of educational research.

  What is crucial to remember as the limit of CR approach is that rather than providing law-like conclusions from research, its retroductive process yields retrospective explanations about

> observed phenomena that helps to improve our theories about the functioning of underlying mechanisms in different contexts.

According to Sayer (2000), realism provides a third way in both cases (of empiricism and interpretivism) by challenging particularly their conceptions regarding the issue of *causation*. In the accounts of Bhaskar's critical realism, then, there are two key elements of causation, namely the *real causal powers* and the *actual causation* (Elder-Vass, 2010, p. 44). In other words, according to Bhaskar's critical realism, causal powers as such are mechanisms that are *real but not necessarily actual*. An explanation for this is that "*[a]ctual events, Bhaskar argues, are not produced by single causes as the covering law model suggests, but by a complex interaction of the causal powers of the entities involved*." (Elder-Vass, 2010, p. 47).

Distinguishing between ontological and epistemological concepts of causality, it can be said that in the critical realism tradition, the concept of causal power is designed to address the ontological problem of causality (Kaidesoja, 2007). Then, due to the above-mentioned distinction made between causal powers and their actualization, Bhaskar proposes that the causal laws need to be analyzed as *tendencies* (see also Fleetwood, 2001). In other words, even the exercised causal powers of things might fail to generate the expected effects at the level of actual events, and therefore, the causal powers of entities *tend* to generate specific outcomes. This means that empirical observations need to be interpreted in light of understanding the counter-effecting mechanisms

which might neutralize the causal powers. It is hence the final intention here to discuss the relationship between the structures and agency in light of the of the concept of tendency (as used in the critical realism tradition).

Critical realism's fundaments

The key premises of critical realism are 'ontological realism' and 'epistemological relativism', respectively meaning that there exists a real world independent of our knowledge, but that our knowledge of that world is contextually and historically conditioned (Bhaskar, 1979; 1975). Together with 'judgmental rationalism', the claim that, despite epistemological relativism, there are rational grounds for preferring some theories over others, these three normative elements regarding theory of scientific enquiry have been characterized as the 'holy trinity' of critical realism (Hartwig, 2007).

Critical realism's inception is, as mentioned earlier, commonly credited to Roy Bhaskar, who developed this metatheory initially in two of his seminal books, first of them being *A Realist Theory of Science* (1975) on the philosophy of science, followed by *The Possibility of Naturalism* (1979) on the philosophy of social sciences. The central philosophical positions taken in these two books, namely transcendental realism and critical naturalism, were then combined into 'critical realism' as a new distinctive position in the philosophy of science and social science. Bhaskar's third classic on these philosophies, entitled *Scientific Realism and Human Emancipation* (1986) had a crucial role in popularizing the term critical realism. The departure point for Bhaskar's classics,

however, remains in the distinction and contrast he makes between *transcendental realism* and *empirical realism* (the latter being equivalent to empiricism). This distinction stems from the difference recognized by Bhaskar (1975) between *transitive* and *intransitive* dimensions of knowledge. In this account, the objects of science constitute the intransitive dimension of science, and the theories developed about them constitute the transitive dimension of science. Hence, a distinction in transcendental realism is made between the real and the empirical, as the latter incorporates the transitive dimension of knowledge to the former's intransitive content, while in empirical realism, the real is identified with the empirical itself.

The recognition of the existence of an intransitive domain in social phenomena, which is the position taken by critical realism, means that generative mechanisms exist that underlie the occurrence of a social event. For Bhaskar, the social reality is seen as "social arrangements that are the products of material but unobservable structures of social relations" (Blaikie, 2000, p. 108). In fact, Bhaskar (1979) counts three basic ontological premises (ontological depth) of transcendental realist social theory about social reality, including *intransitivity*, *transfactulaity*, and *stratification*. The first one, i.e. intransitivity, maintains that the mechanisms that science discovers are existentially independent of the scientific process, while the product of scientific process are fallible. In other words, the intransitive domain of knowledge that answers the question of "what is the phenomena", shall be distinguished from the transitive domain of knowledge that answers the question of "what we

can know about the phenomena". The second premise, i.e. transfactuality, means that the generative mechanisms of nature are universal and operate in closed and open systems alike. In other words, if a phenomenon appears differently in closed versus open systems, the reason shall be sought in co-determining factors. This implies that the domain of the real is distinct and greater than the domain of the actual, and hence, also greater than the domain of empirical. Finally, the third ontological depth, i.e. stratification, refers to rejection of actualism or natural necessity emanating from philosophical problems like induction based on surface sense data. This way a "vertical causality" is recognized between the layers of reality. This is a key feature in the ontological accounts of critical realism which makes distinction between the domains of real, actual and empirical. This has been called a 'stratified ontology', in distinction with 'flat' ontologies proposed by empirical realism. Figure 1 demonstrates the populating entities of each of these domains.

	Domain of real	Domain of actual	Domain of empirical
Mechanisms	X		
Events	X	X	
Experiences	X	X	X

Figure 1 - Bhaskar's three ontological domains and their populating entities (Source: Bhaskar, 1975, p. 56)

According to this stratification, "[…] reality is constituted not only by experiences and the course of actual events, but also by powers,

mechanisms and tendencies - by aspects of reality that underpin, generate or facilitate the actual phenomena that we may (or may not) experience […]" (Bhaskar and Lawson, 1998, p. 5). This is the essence of what distinguishes the ontology of causation in the accounts of critical realism from other prominent philosophical stands on the causal inference. The domain of real represents mechanisms and tendencies which can generate actual events, based on which experiences can be empirically sensed and investigated. The next section deals with the issue of causality in the realm of critical realism in more detail.

Causality in critical realism

The most fundamental aim of critical realism is explanation of real-world phenomena in terms of causality mechanisms underlying the generation of that phenomena. According to critical realists, real world entities, which exist independently of our knowledge, have causal powers (cf. Bhaskar, 1975; Harré and Madden, 1975; Elder-Vass, 2010), which if and when triggered, create events. Accordingly, the objective of science is to uncover the nature and structure of these entities and to explain their causal powers. In line with this, Blaikie (2000) explains that the intransitive structures and mechanisms "[…] are the real essences of things that exist in nature, such essences being their power or tendency to produce effects that can be observed" (Blaikie, 2000, p. 108).

Discussing Bhaskar's conception of 'multiple determination', which draws on interaction between different causal mechanisms affecting events, Elder-Vass (2010) proposes a *level abstracted* versus *laminated*

view of an entity. According to this distinction, the level abstracted view "considers the effects of the whole entity in isolation from the existence or effects of its parts" (Elder-Vass, 2010, p. 49). On the other hand, if a whole entity is treated "quite explicitly as a stratified ensemble of parts at various ontological levels" (Elder-Vass, 2010, p. 49), a laminated view of that entity is taken into account. Consequently, "[t]he total causal impact of a higher level entity conceived of in these laminated terms, then, includes the impact of all its lower-level parts as well as the causal powers that are emergent at its highest level" (Elder-Vass, 2010, p. 50). He then explains that it is due to actual phenomena's being inherently laminated that different real causal mechanisms, each emerging at a specific level, need to be taken into account.

As mentioned earlier, Elder-Vass (2010) clarifies that developing causal explanations, according to critical realism, can be broken down to two complementary processes. One is concerned with identifying causal powers by observing "partial" empirical regularities in order to hypothesize about them. Here, the word partial refers to the fact that only one among several mechanisms affecting the outcome is being studied. The second process concerns identifying the set of causal powers that interact to produce events (or phenomena). In critical realism terms, the former process is called *retroduction* while the latter process is termed *retrodiction* (Lawson, 1997). Therefore, it is needed to complement the identification of entity-specific causal mechanisms – i.e. the "partial" empirical regularities - with the identification of event-specific set of entities that collectively generate the outcome (i.e. the event).

Related to the issue of collective influence of entities, the type of relations between entities is another area of scrutinizing within the realm of critical realism. Sayer (1992) distinguishes between *necessary* and *contingent* relationship between entities. Structure of an entity, in this sense, refers to the set of 'necessary' relationships between the parts that constitute that entity. A contingent relation refers to a relation between entities that "is neither necessary nor impossible that they stand in any particular relation" (Sayer, 1992, p. 89). Based on this, Sayer explains that causal processes could produce quite different results in different contexts, due to the existence of contingent relationships which can generate different effects in different contextual settings. In a similar vein, and based on Giddens' (1979, 1984) discussions of the duality of *agency* and *structure* (see the next section), Pawson and Tilley (1997) argue that explanation of social regularities, patterns and outcomes, rather than coming from the action of independent variables on dependent variables, come from an understanding of mechanisms acting in social *contexts*.

In a similar understanding of the issue at stake, Fleetwood (2001) points to critical realism's alternative notion of causality and law; that of causality as *power* and law as *tendency*. A mechanism, in this approach, refers to a power that is exercised and hence is generating effects. The typical way of acting of a mechanism is then called tendency. Accordingly, "[t]he mechanism does not always bring about certain effects, but *always* tends to." (Fleetwood, *ibid*, p. 10). In other words, a tendency "[…] can be acting yet generate no events at all, or it can be

acting yet generate no event regularities." (Fleetwood, *ibid*, p. 15). Hence, critical realists conceive of a tendency as a force constituent with intransitive mechanisms. Lawson (1997), as Fleetwood (*ibid*) mentions, identifies also four mainstream attempts to interpret Humean laws as tendencies. These, however, as Fleetwood points out, identify a tendency with the outcome or result of some acting force, and not with the force itself.

Apart from these accounts on the ontology of causation, some critical realists have elaborated on causality in a way that links it with the implications for the epistemological dimensions of research. Raduescu and Vessey (2008) compare three most-referenced critical realist explanatory frameworks which deal with the issue of causality, namely Archer's Morphogenetic Cycle (1995), Danermark et al.'s Explanatory Model of Social Science (2002), and Pawson and Tilley's Realistic Evaluation (1997). Archer's Morphogenetic Cycle describes the process based on which transformation or reproduction of social reality emerges as a consequence of temporally distinct but partially overlapping stages of a cycle during which stratified levels of social reality interact. It is based on this interaction that agents contribute to morphogenesis (elaboration) or morphostasis (reproduction) of structures. Danermark *et al*.'s Explanatory Model of Social Science uses what is termed as "structural analysis" to identify and isolate mechanisms and their necessary properties and relations, a task for which the role of theory is emphasized as the real social mechanisms are not observable. This is followed by a "causal analysis" in order to cover the dynamic aspects of

the phenomenon as well. Pawson and Tilley's Realistic Evaluation aims to assess whether a social change can be really considered outcome of a social intervention and uses experiments to establish this relation. The focus of this kind of research is on 'change mechanisms' within a social program, as well as the 'context' in which the program is implemented, which together generate the outcome.

According to the Raduescu and Vessey (*ibid*), while Morphogenetic Cycle deals mainly with explaining the social change, the Explanatory Model of Social Science is mainly concerned with explaining the events, and the Realistic Evaluation approach aims at explaining the regularities (patterns) of outcome. The role of theory and the expected outcome are also comparted across the three frameworks by the authors. Archer's Morphogenetic Cycle uses theory only in identifying emergent properties of agency and structure, and hence, usually does it at the end of the research process. The output of the model is normally historical accounts of emergence of structural, cultural and agency emergent properties. Danermark et al.'s Explanatory Model of Social Science, on the other hand, uses theory early in the research process as it sees this a requirement in order to specify the generation of mechanism by structures (which are not observed). The output of the framework is a set of manifested mechanisms emanating from structures. Pawson and Tilley's Realistic Evaluation uses theories for elaborating on mechanisms and also hypothesizing for development of context-mechanism-outcome (CMO) configuration. The outcome of the framework is a set of CMO configurations about social regularities.

Raduescu and Vessey (2008) suspect that "each framework may be appropriate for addressing different situations with respect to causality in the phenomenon under investigation." (Raduescu and Vessey, *ibid*, p. 38).

By extending critical realist methodological contributions from the likes of Sayer (2002; 1992) and Danermark *et al*. (2002), Bygstad and Munkvold (2011) investigate the methodological aspects of causality for empirical data analysis. They do this by proposing steps involved in identifying structural components of a 'mechanism', given that causality in critical realist perspective is expressed in this term. The steps they suggest for critical realist data analysis include; 1) Description of events; 2) Identification of key components; 3) Theoretical re-description (abduction); 4) Retroduction: Identification of candidate mechanisms; 5) Analysis of selected mechanisms and outcomes; and 6) Validation of explanatory power.

The proposition of these steps is based on the authors' attempt to uncover the tendency of the mechanisms as well as the contextual influences on the phenomena. "Thus, first we need to identify the structural components of the mechanism. Then we must understand how these components interact in order to produce the emergent outcome. Then we need to identify and analyze the outcome tendency. And finally, we need to identify the context (i.e. other mechanisms) that influence on the outcome." (Bygstad and Munkvold, 2011, p. 5). In accordance with these steps, and before some elaboration on the mode of causal inference

regarding structure-agency in critical realism (with which the outcome tendency analysis can be done), the next section draws a more clear picture regarding the developments concerning the agency-structure issue in critical realism, with which the structural components of a mechanism and their interactions are identified.

Structure and agency in critical realism

The debate around the relation between human agency and social structure has for long occupied theorists and scholars across the social scientific subjects[1]. As the issue of primacy of either of them, i.e. agency or structure, over the other, is at the center of this debate, any fundamental discussion concerning the quiddity of *causation* within the realm of social sciences can have important implications for the agency-structure relationship. By taking a very specific position regarding the ontology of causation, critical realism provides, as a philosophical stance in (social) science, a distinct basis for theorizing about the agency-structure relations.

Broadly speaking, social theorists have taken three major positions regarding the relation between human agency and social structure. In one group are those who believe that an agent's activities can mostly be explained as outcome of social structural elements such as norms and resources. According to this view, the social structure cannot be reduced

[1] Marxian mid-19th century accounts on human versus history is often considered as one of the earliest discussions in modern times on the agency-structure dichotomy (cf. Arab, 2016).

to the sum of its agents' actions, as there is an additional effect from *holism*. This approach is usually termed determinism or structuralism. Within the opposing group, a contrasting viewpoint is adopted, asserting that it is the agents that construct and reconstruct the social structure, and hence, social structure can be explained by sum of its agents' social actions. This approach is usually termed voluntarism or intentionalism. The third approach, however, stresses a mutually constitutive relation between agency and structure, giving none of them primacy over the other. Such approaches are referred to as 'dialectical' (McAnulla, 2002).

Among a number of modern sociologists' theoretical approaches that have attempted to overcome the classical structure-agency divide, Anthony Giddens' 'Structuration Theory' and Pierre Bourdieu's 'Theory of Practice' have emerged as two of the most competent accounts (Pérez, 2008). Giddens' structuration theory argues for *duality of structure*, meaning that social structure is the medium but also the outcome of agents' actions (Giddens, 1984, p. 25). In this theory, the social structure is both enabling and constraining the agents' social actions. Giddens introduces *modalities* of structuration as the element connecting structure with agents, meaning that structures, which comprise rules and resources, are translated into actions by means of modalities, which in turn include domination facilities (power resources), interpretive schemes of meaning, and norms (rules). Agents draw on such modalities for interactions within the social system, and thereby either *reproduce* or *transform* the social structures.

Bourdieu's Theory of Practice describes agents as individuals trying to multiply their various sorts of *capital* (economic, social, cultural, symbolic) through engagement in different social *fields*, such as field of work, field of education or field of politics. These fields are structured based on power relationships, and hence constrain individuals' access to the above-mentioned capital resources. Bourdieu introduces another key concept to link the social fields' structure with the agent's actions and that is *habitus*. Habitus is defined by Bourdieu as "a system of generated dispositions integrating past experiences, which functions at every moment in a matrix of perceptions, appreciations and actions and makes possible the achievement of infinitely diversified tasks" (Bourdieu, 1977, p. 83). In other words, habitus explains the unconsciously internalized social schemes that guide agents' actions in different social arena (fields). Then, in order to explain how these factors together shape an agent's social practice, Bourdieu uses the formula: [(Habitus) (Capital)] + Field = Practice (Bourdieu, 1984, p. 101). Hence, Bourdieu analyses practice as resulting from social rules applied in a particular field (structure) in which one's position depends on his relative amount of various capital, which shape his interaction with a field in confluence with his habitus (agency).

Since critical realism emphasizes the co-determination of actual events by a multiplicity of causes, it "[…] provides the framework needed to reconcile the claim for agency with the recognition of the causal impact of external factors on human action (both natural and social)" (Elder-Vass, 2010, p. 87). Similar to Giddens' structuration theory, in the

tradition of critical realism the relationship between agency and structure is perceived as being mutually constituted. Bhaskar's position regarding the structure-agency matter is reflected in his *transformational model of social action* (TMSA), which emphasizes that agents reproduce and transform social structures via their actions (Bhaskar, 1998b; Fleetwood, 2005). According to this view, the causal effects of the structures are always mediated through agents' intentional actions (see Figure 2). What differentiates Bhaskar's TMSA from Giddens' structuration theory is related to the temporal distinction adopted within the TMSA model between agency's action and the creation of structure. As Bhaskar explains it, "*[…] at any moment of time society is pre-given for the individuals who never create it, but merely reproduce or transform it. The social world is always pre-structured. This is a major difference between Bhaskar's transformational model of social activity and Giddens' theory of structuration […]*" (Bhaskar, 1998, p. xvi). Furthermore, for Bhaskar "agents are defined in terms of their tendencies and powers" (Bhaskar, 1979, p. 118) and these are the agents who make conceptions of a social phenomenon through 'transcendental analysis', as there is no possibility for isolating the multiple social structures from each other using experimental or statistical techniques (Kaidesoja, 2009).

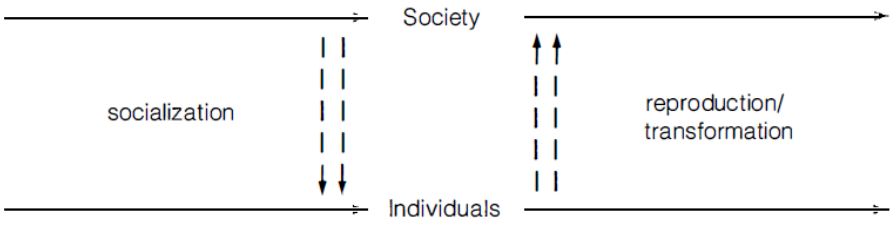

Figure 2 - Transformational model of social action (Source: Bhaskar, 1998c, p. 12)

Nevertheless, the position taken by some of the other theorists within the CR tradition are not exactly the same as Bhaskar's. One reason is, as Kaidesoja (2009, p. 13) points out, related to the "exaggerated openness of social systems in Bhaskar and Sayer's accounts of social phenomena", arguing that empirical regularities and statistical patterns *can* be found in the social life. Back to Raduescu and Vessey's (2008) comparison among three of the most-referenced explanatory CR research accounts, Archer's (1995) Morphogenetic approach to social theory is conceived as an alternative to structuration theory, criticizing this theory for what Archer describes as conflating structure and agency such that their interplay can no longer be studied. As a solution, the Morphogenetic Cycle proposed by Archer adopts what she calls *analytical dualism* instead of Giddens' duality of structure and confers a temporal difference in the existence of structures versus their appropriation by agents. The cycle involves three temporally distinct phases, including 1) structural conditioning; 2) social interaction; and 3) structural elaboration (morphogenesis) or reproduction (morphostasis). In this account, agents mediate the relationship between structural conditioning and structural elaboration, and they do this through their social interaction which

results in either change or reproduction of structures. Mechanisms, which are activated by human actions, are derived from structure, and by Raduescu and Vessey's (*ibid*) assessment, structure is viewed as the most central element in Archer's Morphogenetic Cycle. And since agents are seen as mediators of change in the structure which may act irrationally (and hence, unpredictably), their role is also emphasized well in the cycle. Similar to Archer, in Danermark *et al*.'s (2002) view, structures are the origins of mechanisms. However, agent's role is not emphasized to the same extent as in Archer, even though they enable the change. The reason for this is that here agents are seen as acting always rationally, which means their role is predictable given that the available choices to them is well described by the structures. Finally, as Raduescu and Vessey (2008) explain, for Pawson and Tilley (1997), this is the context of policy mechanisms that is emphasized, not the structure underlying those mechanisms. Their view about the agents is nevertheless similar to Danermark *et al*.'s, acknowledging a rational change-enabler role for agents.

Conclusion: *emergent-tendencies* of agency-structure*s* relations

Since within the framework of critical realism, causation mechanism emanating from the causal power of real, intransitive structures manifests itself as a 'tendency' to generate outcomes, the causal relations between social structure and human agency also becomes exposed to contingency. As a result, the events in terms of, for instance, agential decisions exposed to the same structure, would only 'tend' to

demonstrate a certain pattern. Whether or not the expected event (outcome) would be observed is contingent on several other factors. Firstly, according to critical realism, the set of entities co-determining the outcome (the event) needs to be taken into account. Then, the set of 'necessary' relationships between the entities co-determining the outcome needs to be established. In other words, it makes more sense to speak about agency-structure*s* (with emphasis here on the plural 's') rather than agency-structure, so that the multiplicity of mechanisms at work is better pronounced. This is specifically important since social systems are open systems. As the underlying structures are deemed to be unobservable, the role of theories in describing the partial regularities associated with each agency-structure tendency-generating relation is prominent.

Since each of the structures and their associated mechanisms exert a distinct tendency over the event (e.g. agency's action), rather than individual outcome's pattern, a researcher should look for patterns emerging from the combination of involved tendencies. Accordingly, we can expect observing a pattern of *emergent-tendencies* at the level of actual events. This, I believe, is a key point in understanding the implications of the concept of tendencies within the critical realist research on causalities. Based on this view, finding patterns and regularities within the outcomes from combinatorial tendencies of multiple mechanisms affecting an actual event, is possible at least in terms of a level-abstracted view of the outcome generation. This means that the combination of tendencies from the structures involved in

generating an event for the agent can itself show a pattern of emerging "overall tendencies". Consequently, it is the contingent-type relations between the constituent entities (mechanisms), which are derived from the contextual factors (like culture), that need to be analyzed in terms of their influence on the event (ir)regularities. Finally, since according to the critical realism's principles the domain of empirical is more limited than the domain of actual events, and that transitive domain of knowledge is fallible but also improvable, it is necessary to stay aware of the limitations in our inferences regarding the causality between structures and agency and pursue their improvement through the retroductive research strategy.

Implications for interpreting the empirical findings

It has been widely argued that CR per se does not specify the most appropriate research methods to be used, and it is the relevance level of the domain-specific theory implemented in the research that influences the most appropriate method for conducting the research under a CR paradigm (Raduescu and Vessey, 2009). In this sense, Raduescu and Vessey (*ibid*) argue that the relevance of implemented domain-specific theories can be classified as one of the three types, *strong theory*, *related theory*, or *weak theory*. In turn, the relevance level of theory is deemed to be related to the type of problem at hand in terms of being, (respectively), *structured*, *structurable*, or *unstructured*. In other words, existence of a strong domain-specific theory would lead to having a structured problem at hand, while a related theory would imply that the

problem at hand is structurable, and a weak theory would result in dealing with an unstructured problem.

Given the nature of the main research questions in this dissertation, and the choice made about the underpinning theory (ATT thesis) to investigate them, it can be argued that this research benefits from a 'related theory'. This is explainable by the fact that the extant literature on university-industry collaborations and collaborative doctorates does not offer a very clear theoretical direction in investigating the relation between departmental affiliation of doctoral researchers, and the prevalence of collaborative doctorate schemes and experience gained from them in the form of transferable skills. ATT thesis, however, does offer a theoretical framework related to the discussion of the degree of significance of disciplinary affiliation for academic practices, here manifested in the intersectoral collaborations of doctoral researchers. ATT thesis makes this subject of research "structurable" through its classification of academic disciplines as well as its two alternative hypotheses about the significance level of those disciplinary affiliations for academic practices.

In case of implementing a 'related domain-specific theory', Raduescu and Vessey (*ibid*) propose Danermark *et al*.'s six steps in moving *from the concrete to the abstract and back to the concrete* for linking critical realist ontology to the empirical research. Accordingly, the implications of the theoretical and metatheoretical underpinnings elaborated earlier in

this section of the dissertation for interpretation of the empirical research findings can be explained as follows.

Stage 1: Description focuses on identifying a concrete event or dilemma for further analysis and might use an exploratory study to achieve a more objective account of the phenomenon of interest. Paper I in this dissertation provides an exploratory and inductive study of the phenomenon of the mismatch between doctorate skills and the expectations of industry. This corresponds to CR's starting with the concrete description of the phenomena at the 'empirical layer' before using the 'related theory' at the 'actual layer', and paper I benefits from studying the issue in two different contexts (Sweden and Spain) in order to account for the CR's emphasis on the importance of contextual conditions on manifestations of the mechanisms emanating from the underlying social structures.

Stage 2: Analytical resolution is meant to identify important components or dimensions of the phenomenon of interest. At this stage, abstraction starts which means that the research also moves to the actual layer. Paper II in this dissertation is a conceptual paper and identifies, based on the extant literature, the main antecedents of academics' external engagements. These include *disciplinary*, *regulatory*, and *organizational* dimensions of external engagements, the latter two of which are deemed as comprising contextual mechanisms, while the disciplinary dimension is perceived as a real mechanism in a more essentialist view.

Collaborative doctoral programmes are understood thus as incarnation of the emergent-tendencies from the confluence of these mechanisms.

Stage 3: Abduction / theoretical redescription is about re-describing the components or dimensions of the phenomenon of interest based on existing theories, concepts and explanations about them. Paper II takes on this task by providing an overview of the literature useful for elaborating the disciplinary, regulatory and organizational aspects of collaborative doctoral programmes. It is at this stage that the alternative editions of the ATT thesis are introduced as they help to explain the relation between the aforementioned dimensions in terms of the relative importance of disciplinary dimension over the other dimensions.

Stage 4: Retroduction enquires on the causal mechanisms that are deemed as resulting in observations about the phenomenon dimensions. Taking collaborative doctorate schemes as the phenomenon of interest at the layer of actual, this stage is concerned with retroducing the mechanisms at the layer of real based on the logic embedded in retroduction. Paper II uses the context-mechanism-outcome (CMO) framework in order to integrate the identified dimensions of collaborative doctorates and their empirical outcome (skills learning) while distinguishing between the ontological layers of the phenomena. This framework guides the forthcoming empirical stages of the research.

Stage 5: Comparison between different theories and abstractions assesses the relative explanatory power of the mechanisms and structures identified on stages 3 and 4. Since ATT thesis provides the alternative

versions of the emergent-tendencies from the confluence of disciplinary and contextual mechanisms, i.e. essentialist versus social practice regimes, Paper III in the dissertation investigates which of the regimes apply to the prevalence of collaborative schemes within four Nordic universities. In other words, this Paper assesses the explanatory power of strong versus weak essentialist understanding about the role of disciplinary groups in determining the opportunities for intersectoral collaboration during doctoral education.

Stage 6: Concretization and conceptualization examines how mechanisms manifested in practice interact at different levels under specific contextual conditions, in order to offer causal explanations about the manifested events. Related to the current research, this means that interpreting the empirical data on skills learning experiences gained across different contexts through participation in collaborative doctorate schemes, will lead to inferences about the interrelationships between disciplinary, organizational and regulatory structures underlying the emerging of those manifested events (perceived skills acquisition). Paper IV in this dissertation fulfils this stage by conducting a mixed-method study on acquisition of transferable skills in two universities in Sweden and the Netherlands. The results of the study helps to provide an improved understanding of the relation between disciplinary affiliation and acquisition of transferable skills through further elaboration on the role of organizational and regulatory dimensions of university-industry collaborations as the contextual factors.

4 Research design and methodology

Scholars such as Pratt (1995) and Miller and Tsang (2010) have argued that the methodological implications of critical realism has remained sketchy, and others like Tsang (2014) and Fletcher (2017) hold the view that CR is not associated with any particular set of methods, and that it is just a general methodological framework. Arguing that the main concern of critical realists in the 1970s and 1980s has been the philosophical opposition to positivism, and not so much the methodological implications of CR, Yeung (1997, p. 57) contends that "[t]he realist method must abstract a posteriori causal mechanisms and stipulate their contextual circumstances". Similarly, Sayer (1992) points out that critical realists seek an adequate explanation of past events, but not some law-like relationships with predictive power.

As discussed in the previous part, CR-based research aims at improving theoretical explanations on the tendencies of mechanisms having causal power over the studied phenomena. Eastwood (2011) identified two dominant approaches to theory building in the literature, namely *emergent theory building* and *confirmatory theory testing*. The emergent theory building, as he explains, uses predominantly inductive forms of reasoning, and uses both quantitative and qualitative forms of empirical data. The confirmatory theory testing, on the other hand, uses predominantly deductive forms of reasoning, and has application to both quantitative and qualitative studies. Eastwood (*ibid*) then continues to explain that, due to the critical realists' perception about the

shortcomings of inductive and deductive reasoning approaches, they have embraced a third approach to logical reasoning, called *explanatory theory building*, which nevertheless, supports the emergent and confirmatory modes of theory building in its own way. In this approach, which implements inductive, abductive, retroductive and deductive reasoning, the research process starts from description of concrete phenomena, moving to the identification of its components in the abstract mode, which in turn is followed by comparison of theories and abstractions, and finally by concretization studies of the theorized mechanisms. The final goal in critical realism is, in Bergene's (2007) words, "moving not from the particular to the universal, but from the concrete to the abstract".

Accordingly, and as Eastwood (2011) also discusses it, despite the aforementioned feature of critical realism in distinguishing itself from positivist approach to knowledge generation, the "explanatory theory building" approach does apply deductive logic and confirmatory approaches as part of theory development processes (Haig 2005; Olsen and Morgan 2005; Mingers 2006). Nevertheless, Zachariadis *et al*. (2010) categorize the critical realist critics of statistical modelling into two groups, including those who fully reject statistics as a realist method (except perhaps for descriptive statistics) such as Cartwright (1989), Lawson (1994, 1997) and Fleetwood (1999); and those who assign a value to statistics under the CR perspective, such as Hoover (1997), Bache (2003) and Tsang (2014). The latter group takes the view that while methods like econometrics should not be seen as potent for

extracting laws, they are necessary for uncovering some unobvious regularities. In other words, the quantitative methods are seen here as capable of depicting some partial regularities emanating from, in the CR terms, actualization of mechanisms' tendencies. In harmony with this view, Danermark *et al*. (2002, cited by Eastwood, 2011) argue that "deductive logic can and should be used in analyses of all scientific argument, regardless of what methodology is behind the results presented".

Yeung (1997) also explained that within critical realism, quantitative methods are particularly useful to establish the empirical regularities between objects, which although are not causal relations, but can inform the abstraction of causal mechanisms. Furthermore, he explains, "[q]uantitative methods are also useful in drawing attention to the external and contingent relations between objects". It is important to note that, according to this group of critical realists, these statistical generalizations are only applicable at a specific temporal-spatial context.

As will be elaborated on in the next part, having said all the points above on the role of quantitative methods in a CR-based research, the main mode of identifying the causal mechanisms under the CR is through qualitative research methods (cf. Sayer, 2000). Hence, many of the prominent critical realists promote the use of mixed qualitative and quantitative methods to describe and detect regularities in the phenomena under study (cf. Danermark *et al.*, 2002; Haig, 2005; Zachariadis *et al*., 2010).

At the same time, and as indicated before, a critical realist research process follows a *retroductive* movement (Easton, 2010). This means that to identify generative mechanisms, the researcher seeks to answer the question 'what must be true for the observed phenomena (event) to be possible to emerge'. As Collier (1994) puts it, it is by making analogies with already known theories (called proto-theories) that a critical realist researcher arrives at possible explanations for the observed phenomena. Tsang (2014), however, elaborates on the possible scenarios when conducting the retroduction process, coming up with four different types, namely overcoded, undercoded, creative, and meta-retroduction. Saxena (2019, p. 4) outlines these four types as follows.

> *In overcoded retroduction, the mechanisms are directly available from the literature and the researcher's task is to explain the events employing those mechanisms. In undercoded retroduction, the current body of knowledge suggests a number of potential mechanisms and the researcher determines the ones that best explain the events under consideration. In creative retroduction, the researcher has to invent the mechanism because no suitable mechanisms are available in the literature. Finally, in meta-retroduction, observations do not fit our current conceptual schema and require us to think anew.*

Given the aforementioned indications on the role of ATT thesis in the current research (as the proto-theory with two extremes developed within it), it can be argued that the current research follows an undercoded

retroduction in its overall design. Hu (2018) outlines two general elements for a retroductive study (1) explication of the focal event (domain of the actual) from empirical observations and (2) a hypothesis of the existence of causal powers, mechanisms and their underlying structures that are not subject to direct observation.

Danermark *et al*. (2002) explain that studies aiming at theorizing fundamental conditions of a phenomena would greatly benefit from being organized as comparative case studies. This, furthermore, provides an empirical basis for the retroduction process, which partly implements abductive reasoning. Abduction concerns with re-contextualizing the adopted theory by applying it to a new context, and thereby helps to identify structures underlying the observed phenomena while analyzing the empirical data. Retroduction, then, refers to a creative and recursive application of abduction, induction, and deduction (Chiasson, 2005).

Given all the explanations above, Mingers *et al*.'s (2013) retroductive methodology dubbed as DREI, which involves the following elements, guides the overall design of this research;

Describe the events of interest;

Retroduce explanatory mechanisms;

Eliminate false hypotheses;

Identify the correct mechanisms.

The diagram below shows the application of this framework into the research design in this doctoral dissertation.

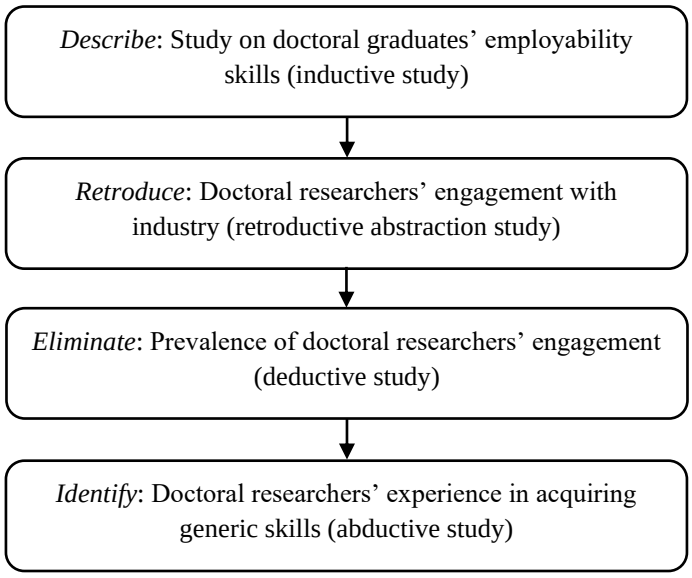

Figure 3 – Design of the dissertation research in an overall retroductive framework

The four papers of this dissertation each address one of the four steps indicated in Figure 3. The next section elaborates further on the methodological choices made in each paper in complying with these research design steps. As indicated earlier, CR methodologists advocate for a mixed-method research design for the empirical parts of the study, while assigning the main role of explanation to the qualitative component of the research. Before moving to the detailed description of methodologies implemented in each paper, the overall role of quantitative and qualitative research in a critical realist inquiry is presented in the following.

The role of quantitative and qualitative research methods within a critical realist mixed-methods research

This section aims to discuss what can be expected from the quantitative and qualitative research parts in a mixed-methods research defined within the paradigm of critical realism (CR). The discussion is contextualized with a research in which the quantitative part seeks to identify the extent of influence of academic disciplines' epistemic feature - as the underlying "real" mechanisms, in the CR terms - on the occurrence of collaboration of doctoral researchers with the non-academic sectors. The qualitative part of the research, then, aims at identifying the effect of contextual mechanisms, like the country-specific higher educational governance and university-specific organizational governance characteristics, on the actualization of the epistemic mechanisms' causal tendencies. In other words, the goal is to understand how the qualitative research methods can combine with the explanatory power of insights gained from the quantitative analysis of underlying structures, in order to provide a context-aware account of causation. This approach to uncovering the causal mechanisms – here, around the occurrence of inter-sectoral collaborations of doctoral researchers – is expected to help avoiding the pitfalls of policymaking without considering the variances with which the objects of policies demonstrate the impact across different contextual settings.

Integrating the causal explanations derived from the quantitative and qualitative methods, however, is not a practice acknowledged equally

across all research paradigms. For instance, Johnson and Gray (2010) point to the dominant view that considers constructivism as the relevant philosophical standpoint for qualitative research, and empiricism as the suitable philosophical stance for quantitative research. Therefore, adopting a mixed methods approach in research can be seen problematic at a first glance. In fact, at a fundamental level, a distinction can be made between two fronts regarding the issue of mixing qualitative and quantitative methods, namely the *purists* and the *pragmatists* (Tashakkori and Teddlie, 1998). While the purists emphasize on mutually exclusiveness in the implementation of the qualitative and quantitative methods, the pragmatists argue that switching between the alternative paradigms underpinning the two methods is needed for a complete analysis.

Nevertheless, more recently a third group of methodologists have been identified by McEvoy and Richards (2006) known as *anti-conflationists*. According to this group, "the methodology should not be conflated with the technical aspects of a method" (McEvoy and Richards, *ibid*, p. 4), implying that combining the methods is appropriate only when a common ontological and epistemological position can be sustained. This approach is underpinned by the philosophy of CR, and according to the authors, helps to circumvent many of the problems that are associated with paradigm switching inherent in the mixed-methods research. Further, Modell (2009) shows that criticisms of triangulation in mixed methods research, deriving from the entrenched paradigm thinking, is addressed by critical realism due to its possibility to accommodate

contingent conditions governing the empirical findings. This is achieved, as Modell explains, based on the implementation of *abductive* reasoning within critical realism.

In fact, within the CR paradigm, methods are chosen in accordance with the nature of the research problem. "*Since a particular object of research may well have different characteristics, it is likely that a mixed-method research strategy (i.e., a variety of methods in the same research study) will be necessary and CR supports this*" (Mingers *et al*., 2013, p. 1). In line with this, scholars such as Fleetwood (2005) and Sayer (2004) consider critical realism as highly potent in bridging the interpretive and functionalist (hypothesis testing) paradigms.

Risjord *et al*. (2001, 2002) identify three purposes for methodological triangulation, including confirmation, completeness, and abductive inspiration. In the case of confirmation, the data from qualitative and quantitative methods corroborate each other, providing a more robust basis for conclusions. Completeness refers to a goal of revealing different aspects of, or perspectives about the same phenomenon. Abductive inspiration, then, is the purpose of triangulation when the goal is to develop a deeper understanding of the processes resulting in an event, through supporting the findings from quantitative data with insights gained from a qualitative research. McEvoy and Richards (*ibid*) suggest that, underpinned by the CR philosophy, an anti-conflationist position in using mixed method approaches is compatible with these three purposes of methodological triangulation.

Danermark *et al*. (2002) count five purposes for mixing qualitative and quantitative methods. These include:

- Validating (testing) a result gained from qualitative analyses by means of quantitative methods;
- Using qualitative method as a preparation for the proper quantitative study;
- Using quantitative and qualitative methods side by side to elucidate a phenomenon in as much detail as possible;
- Exploring the commonality of a qualitatively studied phenomena by quantitative methods;
- Theory development by using both methods to find generative mechanisms.

The authors explain, however, that the first two of these, commit epistemic fallacy from a critical realist point of view, meaning that they "fail to see that reality has ontological depth". Ontological depth refers to the stratified ontology in the CR philosophy, which includes the three layers; the real, the actual, and the empirical.

In the research contextualizing this dissertation, the purpose of mixing methods adheres to the fifth of the above-mentioned ones, i.e. theory development. Related to that, then, Danermark *et al*. (*ibid*) explain that acquiring a deep information about the interaction of the mechanisms behind an observed pattern needs an "intense and focused study of consciously selected cases". Accordingly, empirical regularities derived from quantitative study of a phenomena do not provide sufficient

explanation about the causal mechanisms underlying the phenomena. This is where the qualitative methods come to play a crucial role, as it is only qualitative studies that can reflect the *context-specific structures* and their causal effects.

Pointing to a growing pluralism and variety in the conduct of mixed methods research (MMR), Harrits (2011) points out that such typologies have often been concerned with the issue of status (dominance) of either the qualitative or quantitative method, or the issue of their sequence, neglecting the important issue of how the justification in implementing of MMR is made. In despite of this, he shows that MMR strategies center on a specific epistemological problem. In line with this, Harrits (*ibid*) discusses two paradigmatic strategies in the implementation of MMR, namely the Nested Analysis versus the Praxeological Knowledge, respectively presented by Lieberman (2005) and Bourdieu (1973). Positioning the Nested Analysis within the research paradigm of critical realism, he argues that qualitative and quantitative methods are mutually translatable, as they observe the same reality. Accordingly, a conflicting evidence coming out of the two methods would imply the falsification of the theoretical model used. Otherwise, the two methods supplement each other in explaining the causality, with quantitative analyses shedding light on patterns and correlations while qualitative analyses trace the causal mechanisms.

Similarly, Maxwell and Mittapalli (2010) argue that critical realism facilitates communication and cooperation between the qualitative and

quantitative research, mainly through four aspects of research; the understanding of causality, the relation between the mind and reality, the issue of validity, and diversity. As to the causality, the authors make a contrast between what they refer to as process-based approach to causation (within critical realism) and variance-based approach (mostly associated with positivism), and argue that the former recognizes the explanatory importance of context of the studied phenomena. In contrast, the variance-based approaches address only general patterns using statistical techniques such as regression models. Concerning the relation between mind and reality, the authors highlight the interactive causal relation between individuals' perspective and their situations in critical realism. When it comes to the issue of validity, the authors distinguish between inference quality based upon methodical procedures and the one which also takes context of the study into account in order to test our claims against alternative explanations of the studied phenomena. Finally, Maxwell and Mittapalli point to the acknowledgement of diversity as a real phenomenon and a fundamental fact in the view of critical realism, overcoming the theoretical and methodological shortcomings inherent in purely qualitative or quantitative methods with regards to accommodating diversity.

In the following, the details related to the methodological choices made in each of the three empirical research papers in the dissertation are further described.

Methodological aspects of the dissertation articles

Paper I - Aligning doctoral education with local industrial employers' needs: a comparative case study

This paper aims to describe the issue of doctoral skills in view of its compatibility with the expectations of industry from university postgraduates, and implements an inductive methodology in order to acquire an initially atheoretical account of the concrete issue (see the first step in Danermark *et al*.'s method as well as the first stage in Figure 3).

Choice of the cases

When it comes to the issue of case selection under the CR paradigm, rather than generalizability of some "nomothetic" generalizable cases, *idiographic* case studies are the dominant approach, because it enables researchers to develop context-sensitive causal explanation of the specific phenomena (Wynn and Williams, 2012). Accordingly, and to increase the idiographic as well as explorative nature of this inductive research, two cases of university-adjacent science parks from two very different contexts were chosen. These were Södertälje Science Park (SSCP) in Sweden, and the Research Park of the Autonomous University of Barcelona, or PRUAB (UAB Parc de Recerca) in Spain. These cases represent two dissimilar contexts for university-industry interfaces and collaborations and hence provide good pretext for cross-checking and corroboration of findings about perceived (mis)match between doctoral graduates' skills and the expectations of industry in this regard. As indicated in the second chapter, in Spain most doctoral graduates are

employed by the public sector, while in Sweden transition to industry is much more prevalent. When it comes to the case universities, KTH is a university with focus on engineering subjects, while UAB is a university with more comprehensive coverage of academic fields. Also, the selected science parks represent different histories in terms of intersectoral and institutional backing. In the Spanish case, the PRUAB has emerged from university's initiative while in the Swedish case, the collaboration between industry and public sector (the municipality) has played a more crucial role in founding of the SSCP. Therefore, the two cases represent contexts with specifics very distinguishable from each other, thereby providing possibility for attaining a better idiographic account of the concerned phenomena in Europe.

Selection of informants

Discussing the issue of sample in in-depth interviews in a research which has realism as its epistemological foundation, Crouch and McKenzie (2006, p. 11) point out that "*[r]ather than being systematically selected instances of specific categories of attitudes and responses, here respondents embody and represent meaningful experience–structure links*". Based on this argument, the authors contend that in such a research, "[…] the issue of sample size – as well as representativeness - has little bearing on the project's basic logic" (Crouch and McKenzie, *ibid*, p. 1). In other words, the selection of informants has to do with their ability to reflect adequate amount of information for establishing the relation between the ontological layers of the reality. Accordingly, in this

paper 17 informants were selected (8 from SSCP and 9 from PRUAB) for conducting semi-structured face-to-face interviews. Interviewees were selected from universities, private companies in the two science parks, and the science parks' management. This way, the issue at hand was viewed from a variety of angles in order not to miss any important dimension of the experience-structure links about the issue of doctoral skills and the potential of collaborative doctorate schemes in addressing that issue.

Data collection

The data for this research paper was collected through 17 semi-structured face-to-face interviews between September 2017 and January 2018 at the two respective sites related to the contexts. The core questionnaire of the interviews protocol can be found in the Appendix 1 of the dissertation.

Data analysis

The transcribed texts from the interviews have been analyzed using Gioia methodology while implementing Nvivo software for coding of the interviews data. Gioia method uses an approach similar to Grounded Theory, but identifies themes emerging from the qualitative data in three steps, namely nodes, themes, and aggregate dimensions. These three steps were conducted in such a way that both of the two authors of the paper did the coding at each step and a consensus was reached at the end of each step, thereby triangulating the coding process for achieving a more robust results. While the nodes were coded based on the transcripts of the interviews, the themes were coded based on the topics emerging

from clustering of the nodes while the researchers kept using the informants' words (with no interferences from theoretical knowledge, as is the way in Gioia method). Finally, the aggregate dimensions were identified as common dimensions emerging from both cases. At this stage, the researchers allowed theoretical terminology about the emerging dimensions to be used whenever needed. Consequently, the themes which had emerged from the coding of the clusters of the nodes in each case were mapped in accordance with their respective aggregate dimensions (see page 7 in Paper II), which allowed for a comparative analysis of the two cases with regards to the informants' views on doctorate skills mismatch with industry expectations. This allowed for contrasting the structural specifics underlying the opportunities for addressing such a mismatch.

Contributions of the candidate

The author of this dissertation has been the second author in the Paper I, and except for the data collection and method selection, participated in all other parts of the paper, including the literature review, data analysis, writing up of the findings, discussion and conclusion parts of the paper.

Paper II - Collaboration of doctoral researchers with industry: a critical realist theorization

This paper aims to conceptualize the phenomenon of collaborative doctorates through describing its main antecedents, and positioning this description within a critical realist framework (see the second, third and fourth step in Danermark *et al*.'s method as well as the second stage in

Figure 3). Since this paper does not include empirical research, no further methodological elaborations are provided here.

Paper III - Intersectoral engagement of doctorands: Regime discrepancy between the Academic Territories

This paper aims to verify the explanatory power of the alternative editions of the ATT thesis (essentialist versus the social practice view), and uses a deductive methodology in order to appraise the compatibility of the prevalence of collaborative doctorate schemes with those alternative theories (see the fifth step in Danermark *et al*.'s method as well as the third stage in Figure 3).

Choice of the cases

The aim of this paper is to verify the explanatory power of the specific contextual differences – those most closely related to the academic practices - about the potential differences in the patterns of intersectoral collaboration during doctoral education. Accordingly, the cases were selected from the Scandinavian context with relatively similar cultures in order to minimize the role of contextual differences other than higher education policy and universities' organizational specifics. In selecting the universities, the main criteria has been to choose them from among the comprehensive universities in order to get results for all the four disciplinary groups (according to the ATT thesis) at each university. Universities' willingness to collaborate with the RUNIN project in launching the survey has also been a limiting criterion. Accordingly, four Scandinavian universities, including University of Stavanger (UiS)

from Norway, Linköping University (LiU) and Gothenburg University (GU) from Sweden, and Aalborg University (AAU) from Denmark were found suitable for launching the survey. Except GU, the other universities were participants in the RUNIN project. It should be noted that many other Scandinavian universities were also contacted and invited to participate in the survey, which refused to do so.

Selection of informants

At each of the four universities, the online survey questionnaire was distributed to all the doctoral researchers, irrespective of the type of their doctoral programme (internal candidates, external candidates, collaborative programmes, conventional programmes, etc.). This is because the data was intended to reflect firstly the prevalence of the collaborative doctorate schemes among the total population of doctoral researchers at the case universities, and secondly, to uncover the patterns of this prevalence across all the four concerned disciplinary groups.

Data collection

The designed survey questionnaire was distributed to all doctoral researchers at the four mentioned universities between January and March 2019. One reminder was also sent to the audience of the survey, except for the case of Gothenburg University which was not a member of RUNIN project. The questionnaire of the online survey can be found in the Appendix 2 of the dissertation.

Data analysis

The data analysis in this paper follows a deductive inference logic and aims at verifying the validity of hypotheses which are developed in the paper based on the alternative editions of the ATT thesis. The two hypotheses put to empirical testing ask, respectively, whether the categorization of disciplines based on their cognitive core can explain the patterns of intersectoral engagement by doctoral researchers, and whether the country and university factors which harbor contextual mechanisms mediate the patterning relation mentioned in the first hypothesis.

After cleaning the attained data in order to omit the incomplete responses, the data treatment in this research paper started with coding of the disciplinary affiliations of the survey respondents based on their departmental affiliation, which were categorized into one of the four disciplinary groups, namely hard-pure, hard-applied, soft-pure, and soft-applied disciplines. Consequently, the correlations between these affiliations and engagement in intersectoral collaborations during doctoral education was appraised using logistic regression. This was followed by the analysis of impact from the contextual differences on the patterns of intersectoral collaboration, which was done using moderation effect of country- and university variables in the logistic regression model. Stata software was used in order to conduct the regression analyses, the results of which can be found in the paper.

Contributions of the candidate

All parts of this research were solely conducted by the author of this dissertation, including the design, data collection, and the analyses.

Paper IV - How collaborative doctoral programmes foster acquisition of generic skills? – Professional Doctorate versus Industrial PhD

This paper aims to complement the theory-building process on generic skills acquisition through collaborative doctorates by conducting a comparative mixed-methods study, and implements an abductive methodology in making inferences based on empirical data acquired in two contexts (see the sixth step in Danermark *et al*.'s method as well as the fourth stage in Figure 3).

Choice of the cases

This paper uses a combination of survey and interviews in two contexts in order to inquire both extensively and intensively on mechanisms leading to the acquisition of generic skills by doctoral researchers. As mentioned earlier, under the CR paradigm the qualitative methods have a prominent role in uncovering the context-specific mechanisms. Accordingly, the distinctiveness of the cases for acquiring idiographic accounts of the phenomena was deemed important. At the same time, since the qualitative inquiries are expected to provide meaningful structure-experience explanations, an adequate prevalence of collaborative schemes in the study contexts was seen as crucial.

As mentioned in the previous chapters, the Netherlands and Sweden are deemed as two countries beyond the Anglo-Saxon world in which the professionally oriented doctorates have taken strong roots. Additionally, while in the Netherlands it is the Professional doctorates that have longer tradition and stringer roots, in Sweden it is the Industrial PhD scheme which has gained a similar recognition. Therefore, these two countries were selected as contexts from which meaningful conclusions can be achieved by studying the experience of doctoral researchers from engagement in intersectoral collaborative programmes. Furthermore, hard-applied disciplines, as discussed in the Paper III, are the disciplinary group showing both high prevalence of intersectoral collaboration and high mediating role of contextual mechanisms on that. In selecting the universities, similar to the case of Paper III, the main criteria was to choose comprehensive universities which do have substantive collaborative doctorate programmes in hard-applied sciences, are known for their collaboration with industry, and are willing to participate in the RUNIN project as they were participants in it. Hence, Linköping University (LiU) from Sweden and University of Twente (UT) from the Netherlands were found suitable institutions for launching the survey as well as conducting the interviews from among the participants in the survey.

Selection of informants

For sake of the survey, the online questionnaire was sent by the university to all the doctoral researchers who at the time were conducting

their doctoral studies at the two target universities. The questionnaire was designed in such a way that those doctoral researchers who were involved in collaborative doctoral programmes would continue to answer further questions, while those who were not would not have to go through those further questions.

Concerning the interviews, all those who had responded to the survey at LiU and UT were contacted and invited for the interview. As mentioned earlier, under the CR paradigm, the choice of interviewees aims at analyzing structure-experience linkages. Accordingly, and given the fact that the experiences of "improved learning (acquiring) of the generic skills" is deemed as the outcome of exposure to mechanism of collaborative schemes, the interviewees were selected from both groups of participants in collaborative as well as conventional doctoral programmes at both universities. The aim, hence, was to contrast the difference between the differences at the two contexts between the experiences of participants in conventional and collaborative doctorate programmes. Therefore, in-depth interviews in this study were conducted with 38 doctoral candidates at the two universities, including 19 interviewees from each of the two case universities. In case of the LiU, 7 of the interviewees were Industrial (Organizational) PhD candidates, while the other 12 were conventional PhD candidates. In case of the Dutch university, 8 of the interviewees were PDEng candidates, while the other 11 were conventional doctoral candidates. Overall, the interviews lasted from 22 to 51 minutes, with 31 of them conducted face-

to-face, and the remaining seven conducted virtually (over Skype or phone).

Data collection

The designed survey questionnaire was distributed to all doctoral researchers at the two concerned universities between January and March 2019. The questionnaire of the online survey can be found in the Appendix 2 of the dissertation. The qualitative data was collected through 38 semi-structured interviews (face-to-face in 31 cases, and the other 7 through virtual communication) between March 2019 and June 2019 at the sites related to the two universities. The core questionnaire of the conducted semi-structured interviews can be found in the Appendix 3 of the dissertation.

Data analysis

Data analysis in this paper includes two parts, including the implementation of multiple logistic regression for analyzing the factors correlated with doctoral researchers' perceived acquisition of generic skills, and difference of differences emerging from the comparison of interview data at each context between the participants in conventional and collaborative doctoral programmes. The key to data analyses under a critical realist research is the *retroduction* process. Retroduction means "moving backwards" asking "What must be true in order to make this event possible?". Easton (2010, p. 124) explains this process with regards to its usage in a critical realist case study research as follows:

> *Retroduction is a metaprocess the outcome of which is the identification of mechanisms that explain what caused particular events to occur. Its adoption does not imply that the mechanisms are postulated then data collected or that they are "induced" from the event data. In practice the process is likely to be an iterative one (Dubois & Gadde, 2002). Case studies may employ both deductive and inductive cycles of data collection. Deduction helps to identify the phenomenon of interest, suggests what mechanism may be at play and provide links with previous research and literature. Induction provides event data to be explained and tests the explanations. Finally explanations invoke causal language and the identification of mechanisms and offer the data collected as evidence.*

Next to this, it is worthy to add the guiding words by Bygstad and Munkvold (2011, p. 3), as follows:

> *[…] instead of aiming to generalize at the level of events, critical realism methodology rests on abstract research, which aims at a theoretical description of mechanisms and structures, in order to hypothesize how the observed events can be explained. A typical critical realist research design would be an intensive study, with a limited number of cases, where the researcher systematically analyzes the interplay between the layers […].*

Put together, the retroductive methodology implies that after identification of the types of actualized mechanisms through an initial

deductive inquiry, the intensive research conducted through qualitative methods aims at abstracting (conjecturing) the mechanisms which can more precisely explain why at each context the types of mechanisms proposed by the deductive inquiry manifest the outcomes differently.

Accordingly, in case of the quantitative part in Paper IV, data gained from the survey about the questions concerning the improved disciplinary skills, the duration of intersectoral collaboration, and the existence of (co-)funding by the non-academic partners in such collaborations were all coded as categorical variables, and examined for being correlated with the improved generic skills as the dependent variable. What emerged from the analyses was that the variables related to the contextual structures and mechanisms, i.e. the duration of collaboration and it being cofunded (both of which are reflected in the arrangement of collaborative doctorate as the resultant mechanism) are not able to explain the improved perception of collaborative doctorate candidates about their generic skills. On the other hand, the improved perception about disciplinary skills appeared to be significantly correlated with improved perception about generic skills.

In case of the qualitative part, the core theme emerging from the answer to the interview questions was the degree of comprehensiveness of acquired generic skills based on the categorization of those skills which could help to make retroductive inferences about the underlying structures supporting those skills as outcomes. As mentioned, retroductive reasoning is an intuitive and creative process that

hypothesizes about the generative mechanisms that would explain the empirically attained experiences. Accordingly, all of the interviews were voice-recorded (with the consent of the interviewees) and transcribed before using them in the analysis. Since the interviews were theory-driven, the analysis used interviewees' answers to the questions to confirm or falsify the conjectures underlying the three research questions.

Wynn and Williams (2012, pp. 1-2) point to the involvement of subjective perspectives in the emerging of the outcome of events. "*Specifically, critical realism acknowledges the role of subjective knowledge of social actors in a given situation as well as the existence of independent structures that constrain and enable these actors to pursue certain actions in a particular setting*." This point becomes especially relevant if the unit of analysis are individuals, e.g. doctoral researchers in the case of this research. In such a situation, in-depth interviews are usually a necessary means for data collection to provide an idiographic account of observations.

Healy and Perry (2000) discuss criteria to judge validity and reliability of qualitative research within the realism paradigm. Concerning the issue of generalization, the authors point to the relevance of *analytic generalization*, meaning that 'theory building' rather than 'theory testing' - which is done in case of statistical generalization - applies as the quality criteria. Accordingly, a case study research would seek not only to provide data to confirm or unconfirm a proto-theory, but also to

derive relevant insights for an improved theory building. In line with this, Paper IV has provided new insights about the interrelated development of disciplinary and transferable (generic) skills, showing that the latest edition of the ATT thesis (i.e. social practice view) can explain the learning of generic skills among the studied doctoral researchers if the harmonized social practice of disciplines is given a higher explanatory significance than the other contextual factors related to the intensity of the intersectoral collaborations. This finding seems to be transfactually consistent across the studied contexts, implying that the findings can be analytically generalized to explain the causes of the observations.

Contributions of the candidate

All parts of this research were solely conducted by the author of this dissertation, including the design, data collection, and the analyses.

5 Summary of the papers

In the research design section, I presented the four stages of research in this dissertation (Figure 3), starting with an inductive research to problematize doctoral graduates' employability skills. This in fact corresponds to critical realism's start with concrete phenomena (Sayer, 1992). The first article of this dissertation, entitled *Aligning doctoral education with local industrial employers' needs: A comparative case study*, addresses this step through conducting a grounded-theory-like study of perceptions held by industrial employers at two science parks concerning the employability skills of doctoral graduates. Being located in two different settings for intersectoral collaborations (Spain and Sweden), the two science parks represent, for doctoral graduates from STEM fields, potential employment destinations embedded in two different supportive ecosystems for knowledge economy. The data for the paper is collected using semi-structured interviews with science park-based employers as well as the science park management staff and academics in relation with doctoral education. Results from the data analysis demonstrates that for the employers at firms, there exist a clear perception of skills mismatch between doctoral skills and what they consider as employability skills. The findings show, furthermore, the significance of contextual factors such as the cultural, the institutional and the industrial specifics in facilitating the dialogue between universities and firms on the issues of demand for skills and the design of supportive and collaborative schemes (between universities and

industry) for supplying those skills. Provision of opportunities for acquisition of generic skills through work placement or academic courses with the involvement of industry is specifically favored by firms for this purpose, as it was also indicated by some of the employers' preference for graduates of Industrial PhD programmes.

As indicated in the Figure 3, the next stage in this doctoral research is to conduct a retroductive abstraction study on the engagement of doctoral researchers with industry, as this is the "event" conjectured to influence their skills (as outcome). This corresponds to turning from concrete to abstract (Sayer, *ibid*), from which it is expected to decompose the phenomena into its components. Within the critical realist accounts, such a decomposition is meant to stratify the phenomena by distinguishing between its more essential aspects and the more circumstantial ones (Wagner, 2016). The second article of this dissertation, entitled *Collaboration of doctoral researchers with industry: A critical realist theorization*, strives to deal with this step, by reviewing the literature most relevant to purpose of the abstraction of doctorands' engagement with industry. Using the categories of antecedents identified in the literature for the engagement of academics with industry, the paper elaborates, theoretically, on the disciplinary, regulatory and organizational factors derived from the literature related to doctoral education. Consequently, a critical realist framework, known as context-mechanism-outcome configuration (CMOc), is implemented to integrate the discussed antecedents into an overall conceptual model. Through distinguishing between the disciplinary and contextual factors as

structures underlying the occurrence of collaborative doctoral programmes, the proposed model sets the stage for the empirical research for evaluating the explanatory power of alternative proto-theories, i.e. essentialist versus social-practice-based editions of the Academic Tribes and Territories (ATT) thesis.

The next paper in the dissertation uses a deductive methodology in order to take the first step in moving back from the abstract – the conceptualization done in the second paper - to the concrete, i.e. the empirical assessment of the theorized alternative explanations. This third article of this dissertation is entitled *Intersectoral engagement of doctorands: Regime discrepancy between the Academic Territories*. Data collected through a survey of doctoral candidates at a total of four universities from three countries (Sweden, Norway, and Denmark) serves in the paper the purpose of examining alternative hypotheses developed based on the ATT thesis. For conducting the data analysis, firstly the departmental affiliations of doctoral candidates surveyed are categorized into four groups, namely hard-pure, hard-applied, soft-pure, and soft-applied disciplines. Using regression analysis, the paper examines whether this categorization is potent enough in explaining the patterns (demi-regularities) of intersectoral engagement by doctorands across the four universities and three countries. The results indicate that two regimes of intersectoral engagement can be distinguished for the surveyed doctoral researchers. For those affiliated with hard-pure and soft-applied disciplines, the essentialist regime seems capable of explaining their collaboration patterns, meaning that the prevalence of

intersectoral collaborations is consistent across the universities covered by the survey across the three countries. On the other hand, for those affiliated with hard-applied and soft-pure disciplines, the social practice regime proves fitting the pattern observed across the surveyed universities, implying that these disciplines give significantly varying degrees of opportunities for intersectoral collaboration over different contexts in which the universities are posited.

As the third paper shows that, specifically in case of academic fields within the hard-applied group of disciplines, the contextual mechanisms have a significant influence on the intersectoral collaborations of doctoral researchers, it would be plausible to expect varying outcomes from their external engagements in terms of the acquisition (learning) of generic skills. In order to concretize and *contextualize* the findings about the outcomes of doctorands' intersectoral engagements, which according to Danermark *et al*. (2002) and (Sayer, *ibid*) is the needed last step for concluding a critical realist research, an abductive research constitutes the fourth paper in the dissertation. In fact, this paper serves two main purposes at the same time; implementing a mixed *qualitative* and *quantitative* research in order to retroduce the mechanisms underlying the learning of generic skills; and conducting a comparative case study in two distinct contexts in order to distinguish between *transfactual* and *contingent*.

Hence, the fourth article, which has the title *How collaborative doctoral programmes foster acquisition of generic skills? – Professional*

Doctorate versus Industrial PhD, implements data from the survey of, as well as in-depth interviews with doctoral researchers from two universities, one in Sweden and the other in The Netherlands. The survey data are analyzed using multiple logistic regression to examine whether the duration of intersectoral engagement, its funding mechanism, and its impact on improving the discipline-specific knowledge of doctorands are correlated with the improvement of their generic skills. The results indicate that only the improvement in discipline-specific knowledge of participants in collaborative doctoral schemes is (positively) associated with the improvement of their generic skills. Further investigation obtained through interview data, then, shows that such an improvement is best achieved when there is a balanced and concurrent acquisition of skills between the discipline-specific and generic skills. In other words, collaborative doctoral programmes which provide the possibility of acquiring the academic and generic (professional) skills in tandem, are perceived by doctoral candidates as better in preparing them for non-academic careers. Consequently, it can be argued that in the context where academic and non-academic partners collaborate more in the development of the collaborative doctorate programme's content, and on the academe's side do this at the level of departments (rather than university level), best results in terms of equipping doctoral candidates with generic skills can be expected. As a stylized fact, this can be seen from the case of the Dutch university, where Professional Doctorate programmes are defined with a balanced weight of credits from its academic and practical parts (about 60 EC from each), and that these

discipline-specific programmes are always drawn up in close consultation between the "programme heads" and the external organization (firm).

Table 1 summarizes the key aspects of the four articles included in this dissertation, as well as their latest situation in terms of the stage at the publication process at the time of submitting this dissertation.

Article No.	Theoretical / empirical	Topic	Methodology	Data	Latest situation by August 2020
I	empirical	skills for doctoral careers in industry	inductive	interviews at two science parks in Sweden and Spain	Published in *European Planning Studies*
II	theoretical	theorizing the collaborative doctorate	retroductive	literature	Published in *Industry and Higher Education*
III	empirical	prevalence of collaborative doctorate across disciplines	deductive	survey of doctoral candidates at four Scandinavian universities	Submitted to *Higher Education Policy*
IV	empirical	generic skills acquisition through collaborative doctorate	abductive	survey and interviews with doctoral candidates at two universities in Sweden and The Netherlands	Ready for submission.

Table 2 - The key aspects of the papers included in the dissertation

6 Discussion of the findings and limitations

In order to discuss the findings of the four articles included in this dissertation, they need to be positioned within the overall research meta-theory (paradigm) of this doctoral research, namely that of critical realism. This is crucial due to the specific ontological, epistemological and methodological stand of critical realism which have implications for data analysis, and interpretation of the findings from that. The key to the distinctiveness of these aspects in critical realism from other research paradigms is the layered ontology. As introduced earlier in the section on research paradigm, this includes the layers of empirical, actual and real. In accordance with this layered ontology, the acquisition (learning) of generic skills, as perceived by the agents (i.e. doctoral candidates), constitutes the empirical layer which can be "observed" (empirically investigated) by the researcher. The undertaken intersectoral collaborative doctorate programmes, then, constitute the layer of actual, which is the layer to which the researcher has only partial access through the empirical data. The aim of data analysis within a critical realist research is then to generalize in the form of theoretical explanation of mechanisms leading to the actual events, which in turn emanate from the ontological layer of "real", where the underlying structures have generative tendencies.

Danermark *et al*. (2002), and closely similar, Bygstad and Munkvold (2011) provide some of the clearest methodological steps to be

undertaken in a critical realist research. While the former had proposed the respective steps for research within social sciences, the latter aimed to contribute to the implementation of critical realism in research on technological innovation within the area of information systems. Table 2 shows how the four articles in this dissertation address the six steps proposed in Danermark *et al*. (2002) and Bygstad and Munkvold (2011).

Paper	Issue addressed in the paper	Corresponding step in Danermark *et al*. (2002) methodology	Corresponding step in Bygstad and Munkvold (2011) methodology
I & II	Doctorate skills mismatch with industry career needs (paper I) Characteristics of collaborative doctorate (paper II)	Description of events	Description of events
II	Antecedents of doctoral candidates' engagement with industry	Identification of key components or dimensions	Identification of key components
II	Redescription of engagement antecedents as components of CMO explanatory model	Theoretical redescription (abduction) of components or dimensions	Theoretical re-description (abduction)
II	Identification of alternative proto-theories on the relation between disciplines and engagement based on ATT thesis	Retroduction: identification of candidate mechanisms	Retroduction: identification of candidate mechanisms
III & IV	Assessing the relevance of the two alternative accounts within the ATT thesis in explaining the prevalence of collaborative doctorate (paper III) Assessing the relevance of the disciplinary and contextual mechanisms in explaining the learning outcome of collaborative doctorate (paper IV)	Comparison of relative explanatory power of alternative theories and mechanisms	Analysis of selected mechanisms and outcomes
IV	Retroducing the transfactual mechanisms and structures capable of explaining the contextualized outcome of collaborative doctorate	Concretization and contextualization of structures and mechanisms	Validation of explanatory power

Table 3 - The correspondence of the dissertation papers to the methodological steps in critical realism

As the Table 2 indicates, a combination of inductive, deductive, abductive and retroductive inference logics are applied in different stages on this research. What distinguishes the critical realist approach from other research paradigms, however, is its overall reliance on retroductive logic, which is a mode of inference in which a phenomenon is explained by postulating mechanisms that are capable of producing it (Sayer, 1992). In doing this, the main purpose of retroduction is to separate the necessary conditions from contingent circumstances (Sayer, *ibid*). Accordingly, the aim in this doctoral research is to identify the learning (infra)structures which can give rise to more effective mechanisms supporting the acquisition of generic skills by doctoral researchers. Consequently, there can be devised policies which target supporting those (infra)structures, keeping in mind that the necessary conditions are not enough, and require supplementing by context-aware, contingent circumstances to deliver the best outcome. Discussing the policy mixes around innovation, Flanagan and his co-authors (2016; 2011) advocate for greater insights from context-sensitive approaches to innovation policy, instead of treating such policies as tools from a toolbox. Implementing a critical realist approach serves precisely this purpose by situating the real mechanisms within the respective context of their actualization for sake of generating the sought explanations.

Any critical realist research starts with observation of concerned events, and the observations can be made by the researcher or by the researcher's informants (Sayer, 1992). In line with this, the whole of the first paper

and a part of the second paper are dedicated to the description of the concerned phenomena at different ontological layers. The first paper uses primary data to discuss the discrepancy perceived by employers in industry between the skills they look for and the skills they believe doctoral graduates possess. Thus, the first paper provides a first-hand impression about the relevance of the topic under investigation in the whole of this dissertation and its constituent papers and it does this based on the findings from two different contexts. Hence, besides describing the concerned phenomena in terms of the need for improvements in learning of professional (generic) skills, the comparative nature of the paper makes it possible to already open up the discussion to the contextual specificities which have potential to influence the mechanisms lying in university-industry relations in support of the acquisition of those skills.

Then, the second paper moves to the layer of 'actual' event, i.e. intersectoral collaborations around doctoral training, starting with the description of such collaborations through scholarly reports as informants of such events. This way, the second paper starts the process of abstraction, which is the basis for identification of key components of the concerned phenomena within the critical realist approach. Based on existing scholarly comprehensive review of literature, the paper identifies disciplinary, organizational and regulatory dimensions of university-industry engagements to be constituents of those key components (antecedents). In fact, the factor of individual characteristics of academics, which is identified as another antecedent by the referenced

systematic review, is left aside in the next step, i.e. the theoretical redescription of components. This is done due to a clear reason, and that is to the critical realist approach's priority on uncovering the structures as the conditioning factors of the actions of agents. Accordingly, the individual factor is left as a *contingent* element, as opposed to the structures which are capable of explaining the *necessary* relations in the emerging of phenomena. This approach to the formulation of the conceptual framework can then be reflected in the context-mechanism-outcome configuration which the second paper proposes for sake of theoretical redescription, i.e. the third stage in the implemented six-stage methodology. The reason for this compatibility is that the context is considered within the critical realist accounts to be the source of contingent mechanisms, and the factor of individual, if proven significant based on the social-practice-based understanding of the ATT thesis, exerts its causality through interaction with the contextual elements and structures.

In fact, the second paper also sets the stage for the fourth step of the methodology, i.e. identification of alternative mechanisms, by introducing the ATT thesis and the two alternative positions developed within it over time concerning the deterministic power of academic disciplinary groups in shaping the professional behaviour of academics. Through nesting the ATT thesis within the overall CMOc framework, the second paper already distinguishes between contextual (i.e. regulatory and organizational) versus disciplinary mechanisms, setting the stage for the empirical assessment of the explanatory power of the

two alternative proto-theories derived from the ATT thesis. Consequently, the third paper uses primary data collected through a survey of doctoral researchers' intersectoral collaborations at four Scandinavian universities in order to trigger the data-driven retroductive inference process. This stage, sometimes referred to as "extensive research" (Sayer, 2000), while not intended for acquiring a full account of the causality of disciplinary groups on intersectoral engagement of doctoral researchers, is nonetheless considered as providing some general patterns. Also, the resulting patterns are deemed as implying to and setting the direction for the "intensive research" (Sayer, *ibid*) which aims at acquiring in-depth knowledge of the impacts of intersectoral engagement through implementation of qualitative methods in the fourth paper.

The third paper, however, concludes from the analysis of survey data that there exists a discrepancy between the patterns of engagement among doctoral researchers affiliated with different disciplinary (cognitive) groups. In other words, in the studied context of four Scandinavian universities, the co-determining power of contextual factors appears to be more significant for the intersectoral engagement opportunities of those affiliated with hard-applied and soft-pure disciplines. This finding points to the suitability of studying collaborative doctorate programmes around academic fields like engineering for the in-depth inquiry on the co-causal influence of contextual mechanisms. As Pinkstone (2002, p. 563) puts it, "the nature of a particular contrastive demi-reg will often give us a hint to the direction in which we should start looking for

answers". Accordingly, the contrastive pattern (demi-regularity) found between the HA/SP and HP/SA disciplines points to the necessity of further studying the disciplines influenced by the contextual mechanisms in their experience-generating effect.

Hence, the fourth paper is designed around a comparative study of experience of doctoral researchers participating in two different collaborative doctoral programmes with industry in two different country contexts. The choice of studying the experience of candidates in Professional Doctorate in Engineering and those in Industrial PhD links to the findings in the third paper about the relevance of hard-applied disciplines for studying the co-causation power of contextual mechanisms. The fourth paper uses a mixed-method approach by combining extensive and intensive research design methods, i.e. survey and in-depth interviews. Furthermore, in each country (university) context, the comparison of experiences of conventional and collaborative doctoral programmes provides more authenticity to the informative value of data for the final contextual comparison. The combination of data gained through the survey and interviews demonstrate that rather than the factors related to the intensity of relation between doctoral researchers and industry, indicated by the funding and the duration of the collaboration, it is the harmonized and balanced development of disciplinary and generic skills that makes the best outcome in terms of preparing for careers in industry. This finding, then, when applied by a retroductive inference approach, implies the interconnectedness of disciplinary and generic skills, necessitating a close collaboration

between industry and academic departments or faculties in designing collaborative doctoral programmes.

As the results from a critical realist research are considered as generalizable to the theory-building, e.g. by using the CMOc framework in this thesis, the transfactual mechanisms derived from such findings are more prone for examination and validation in other contexts. More specifically, the interwoven development of disciplinary and generic skills in doctoral researchers, which points to a cognitive relation between the two learning areas, are worth verification through testing of the mechanism in other contexts. For instance, these findings of the fourth paper also find support from recent studies in the Russian and Canadian context. Bekova and Dzhafarova (2019) studied the learning experience of doctoral students in Russia from their combining of work and studies, which according to the authors, is a rather common practice there. The authors conclude from their study that balancing work and study can benefit both the academic performance and professional experiences of PhD students, "only in case the work duties correspond to the thesis topic". In the Canadian context, Berdahl and Malloy (2019) who surveyed chairs of political science departments concerning their engagement in doctoral professional development, came to the conclusion that graduate faculties should develop collaborative doctorate models which are responsive to disciplinary needs, and hence should consult departments about programme design. But interestingly, as a study drawing its conclusions from a soft-pure discipline, Berdahl and Malloy's study still proposes keeping the professional development

programmes at graduate faculty rather than the department level. This, in fact, might be seen as a point for discussion whether the disciplines – as found in the current research – more prone to the "social practice" – such as SP and HA fields in the contexts concerned in this research - are less intensely in need of disciplinary intervention in the design of transferable skills training modules.

Further to the implications for the specific area of university-industry collaborations around doctoral education and training, the final findings of this thesis can find connotation in other closely related problema areas of inquiry. For instance, while the current thesis concentrated on the non-commercialisation types of university-industry engagements, those of a commercialisation type might also be considered as benefitting from the findings here. Rasmussen *et al*. (2014), for instance, showed that the departmental context hugely influences the development of entrepreneurial competencies in academics, and the consequent development of spin-off activities among them. Apparently, this resonates with the current thesis' emphasis on the interrelation between the development of disciplinary and generic (professional) skills.

Limitations of the research

The limitations of the research conducted in this dissertation can be articulated in relation to the epistemological relativism which is characteristic of any critical realist research, meaning that the acquired knowledge is contextually conditioned (Bhaskar, 1979). As mentioned in the section on 'research design and methodology', a CR-based inquiry

seeks to provide context-specific explanations about the emerging of a phenomena, rather than making statistical generalizations based on the observed surface-level empirics. Accordingly, the following points demarcate the limitations of the knowledge gained based on the empirical findings in the papers included in this dissertation:

1) In assessing the explanatory power of the alternative editions of the ATT thesis about the prevalence of intersectoral collaborations during doctoral education across four Nordic universities, it was concluded that the "weak essentialist" edition of the thesis, also known as "social practice" view, is better able to explain the observed patterns in some disciplinary groups, while strong essentialist edition corresponds to the observed patterns in other disciplinary groups. It is necessary to note that these so-called contrastive demi-regularities point to the possibility of disparity between disciplinary groups in terms of their deterministic power in shaping the opportunities for intersectoral collaborations, rather than being valid for extrapolation to other contexts. In other words, the theoretical inferences made about the unobservable mechanisms underlying the emerging of disparities is of more importance here, rather than making statistical generalizations about the deterministic power of the epistemic core of the disciplinary groups. Therefore, unlike a situation in which similar research would be conducted under positivist paradigm, the results from this research is not

claimed to be able to make assertions about the deterministic power of individual disciplinary groups across space and time.

2) Limits inherent in the abductive and retroductive reasoning should be taken into account when dealing with the implications of this research. In investigating the contextual mechanisms interacting with the disciplinary factor in shaping the pursued outcome, i.e. the perceived acquisition of generic skills, the two factors of co-funding and duration of intersectoral engagement were singled out as the most common aspects in collaborative doctorate programmes, and represent organizational and regulatory dimensions of the phenomena found in every context. Interestingly, the research showed that it has been doctorands' perception of improved discipline-related learning that proved significant in correlating with the improved learning of generic skills. This finding shows that despite their prevalence, the variations in the co-funding and duration of intersectoral collaborations cannot explain the contextuality of "social practice of disciplines". Rather, it has been the intensity of involvement of non-academic partners in designing the collaborative doctorate schemes which affects the success of these mechanisms through enabling a balanced and parallel development of generic and disciplinary skills. Therefore, due to the CR's emphasis on intensive (rather than extensive) research, its process orientation, and the search for transfactual elements, other factors and mechanisms influencing collaborative doctorates which are less

generalizable to the other contexts, need further research in order to shed light on their potential interactive effect on the outcome generation, i.e. acquisition of generic skills. As mentioned earlier, the transitive knowledge gained in a CR-based research is deemed as a hypothesis which is improvable through gaining additional information from the same or other contexts.

3) Another limitation relates to the transitive nature of knowledge gained through CR research. The knowledge gained about the experiences of the *agents*, i.e. doctoral researchers, from their exposure to their respective collaborative doctorates (mechanisms), is considered as reflecting their transitive knowledge about the efficiency of some intransitive *structures*. The knowledge of transitive domain, then, is deemed as fallible based on attaining further information. Accordingly, doctoral researchers' perceptions about their acquired generic skills might be improved based on gaining additional knowledge, e.g. through their exposure to the contexts where they can apply those skills. Therefore, future research can benefit from combining empirical data about doctorands' perceptions with doctoral graduates' performance in implementing generic (transferable) skills. This will improve the reliability of data regarding the acquisition of generic skills by adding a less subjective perspective to the transitive domain of knowledge, availing further data for retroducing the intransitive domain (structures).

7 Contribution to the research field

The contribution of this doctoral dissertation to the research field of university-industry relations - and the broader field of innovation systems - is multifaceted. This pertains to the literature streams and theoretical approach utilized, meta-theoretical and methodological choices made, as well as the resultant knowledge gained.

From the theoretical point of view, the current dissertation established a bridge between university-industry relations literature and higher education research literature through adopting the ATT thesis at the core of its theoretical base. This starts with the introduction of the ATT thesis in the second paper and stretches to the third and fourth papers whereby the implications of mechanisms suggested by the ATT thesis for the intersectoral engagement of doctoral candidates is empirically investigated. Consequently, this thesis has arguably complied with the call by Pinheiro *et al.* (2012) by opening up to the contextual (local) factors about which these authors had called for further research in order to complement the comprehension of academics' external engagements based on their knowledge domain (departmental) affiliation.

From the methodological point of view, then, the research paradigm selected to underpin the enquiries in this dissertation can be understood as contributing to a novel approach to the research within the area of university-industry relations. Taking a critical realist meta-theoretical approach helped to move beyond a purely positivist world of correlated variables and to comprehend the academic discipline as an ontologically

deeper layer of the phenomenon of intersectoral collaboration itself. In other words, together with the ATT thesis, the CR approach made it possible to distinguish between epistemic core of academic knowledge domain as a "mechanism" which is nested within the occurrence of the "event" of collaboration and learning, and the other mechanisms which actualize only contingently and based on contextual circumstances. As a consequence, this research has pinned the disciplinary factor as the "real" structure around of which the interactions with other organizational and institutional factors take shape and lead to various experiences for academics in general and doctoral researchers in particular.

When it comes to the results and findings of the research, the papers included in this dissertation have sequentially formed a series of interconnected theoretical and policy-related contributions to the literature. The first paper, to the best of our knowledge, juxtaposes for the first time the literature around science parks with the literature around doctorate careers and skills. In addition, the paper utilizes the typological and contextual heterogeneity of the studied science parks as a sort of data source triangulation in order to strengthen the inductive inferences concerning doctorate skills mismatch argument. Of special importance is the comparison made between the supportive innovation ecosystems within which the science parks are embedded, and how these eventually lead to different modes of opportunities for acquiring the generic skills (course-based vs. work placement).

The second paper, then, departs from university-industry relations literature and by combining it with a critical realist methodological procedure, arrives at a new analytical model for studying the engagement of doctoral researchers with industry. In this model, the ontological layers of the phenomenon of 'skills acquisition through collaboration' are presented with distinction made between the contextual structures, the disciplinary mechanism and the outcome. This new analytical (conceptual) framework not only paves the way for the consequent empirical studies, but also provides the overall framework for the later retroductive inference resulting from those studies.

As the result of data analysis, the third paper introduces the notion of *regimes of intersectoral engagement*, based on which it is argued that depending on the disciplinary affiliation category, doctoral candidates surveyed are differently exposed to the influence of contextual factors (as opposed to the disciplinary factor) in getting opportunity for collaborating with non-academic sectors. This has important implications for policies targeting the improvement of skills acquisition among doctoral candidates in preparation of non-academic careers. Notably, in the studied context of Nordic universities, it appears that hard-pure and soft-applied disciplines influence the engagement opportunities quite homogeneously across different countries. Hence, the increasing of engagement opportunities seems to be subject to introducing further interdisciplinarity rather than regulatory and organizational facilitation. On the other hand, hard-applied and soft-pure disciplines show more openness to the role of social practicing, implying

that contextual elements play stronger role in improving the intersectoral engagement possibilities for doctoral researchers. Hence, the results from the third paper also contribute to the debate around the ATT thesis itself in terms of the viability of essentialist approach by suggesting a nuanced approach in perceiving the generative power of epistemic core of academic disciplines.

Finally, the fourth paper wraps up the CR-based methodological steps undertaken in the four papers by retroductively identifying the way contextual mechanisms interact with and influence the collaborative learning by doctoral candidates. As such, the fourth paper contributes a distinctive higher education policy recommendation by arguing that the acquisition of generic skills needs to be arranged for in close connection with the learning of disciplinary knowledge. The key message from the paper is that the academic structures (such as graduate schools or doctoral schools) concerned with this issue need to be defined at the faculty or department level rather than university level. Furthermore, collaborative doctorate programmes shall embrace more intense involvement of industry in the designing of doctoral training curricula with the aim of ensuring a more balanced and parallel development of academic and professional skills during doctoral education.

Moreover, the findings of this research can contribute to the socio-economic stream within innovation studies, where interactive learning is the core theme. As Lundvall (2013) had also called for opening up of this field to the specificities of labour markets and education institutions, the

findings of this dissertation has proposed a framework for establishing a link between the requirements of knowledge-intensive labour markets (in terms of skills) and higher education policies aiming at meeting those needs through systemic collaborative schemes.

8 Conclusion

The research conducted in this dissertation is framed within the context of Europe's ambition for transitioning of its constitutive economies into knowledge-based and innovative ones. Doctoral graduates play a prominent role in this transition, and the policies around doctoral education need to comply with implications of such a transition for doctorate careers. In line with this, European Commission (EC, 2011) has communicated principles for innovative doctoral training across the European Research Area, two of which include *exposure to industry and other relevant employment sectors* and *transferable skills training*. These two principles were integrated parts of the main research questions of this dissertation, with the aim of understanding if and how exposure to industry through collaborative doctoral training helps to improve doctoral candidates gaining transferable (generic) skills.

There have been indications in the university-industry collaborations literature that academic research groups having long-term collaborations with industry show better scientific productivity (cf. Garcia *et al*., 2019). More specifically related to the current research, it has been shown that collaborative PhD projects outperform non-collaborative PhD projects both in terms of industrial performance and academic performance (Salimi *et al*., 2015). Nevertheless, there has not been an adequate attention paid so far in the literature to the *mechanisms* through which collaborative doctoral programmes can yield most comprehensive result in terms of the acquisition of transferable (generic) skills.

Acknowledging the apparent disparity among academic disciplines in terms of opportunity for collaboration with non-academic sectors, the current doctoral research took a distinctive approach by conceptualizing disciplines as harboring a generative mechanism embedded within the occurrence of intersectoral collaborations as such. Taking this viewpoint, which corresponds with the implications of the ATT thesis as a prominent theory on the significance of disciplines for the professional activities of academics, provided a strong incentive for taking a critical realist approach as the overarching research paradigm.

The revised edition evolved within the ATT thesis, as well as the adopted critical realist epistemological approach, both pointed to the significance of assessing the *contextuality* of the actualization of disciplinary mechanism in shaping the intersectoral collaboration experiences. In other words, both the theoretical and epistemological stand points undertaken implied that the enquiry on the influence of disciplinary groups on collaborative learning experiences needs to be examined in light of practices specific to the local organizational and regulatory norms. The formation of various schemes for collaborative doctoral programmes in different higher education system contexts at the country and university level can be perceived as the incarnation of such organizational and regulatory norms. Taking the CMOc framework into account, then, it can be argued that a social-practice-based intersectoral collaboration would open up the learning process more to the contextual (i.e. organizational and regulatory) factors (as opposed to the disciplinary factor). Accordingly, whether all the interpersonal, instrumental and

systemic generic skills are supported by collaborative doctoral programmes would be subject to the degree to which those contextual factors are designed in harmony with the training needs of disciplinary skills. This can explain why the enquired PDEng doctoral researchers have experienced a more comprehensive upskilling in generic attributes, as through the inclusion of professional societies, this programme is more closely knitted to the disciplinary attributes (of engineering), compared to the Industrial PhD which is arguably more open in terms of the disciplinary relevance.

The notion of 'emergent properties' is used by critical realists to refer to irreducibility of properties at each ontological level to the deeper levels. In a conceptualization similar to this, the current dissertation proposed the notion of 'emergent-tendencies' to refer to a combined causal effect of various social structures on an agent, with the possibility that the resultant behaviour can show attributes more than just the sum of individual cause-and-effects. Adopting this argument to the findings of this doctoral research, it can be contended that the systemic type of generic skills, such as leadership or project management, which emerge as a set of skills combining those related to instrumental (disciplinary) and interpersonal (social) skills, tend to develop better in doctoral researchers where the underlying educational infrastructure itself is attributed better with a systemic approach to learning. This point was not only evident in the findings of the fourth paper through the doctoral researchers' learning outcome from the PDEng programme which had in fact involvement of professional society of engineers in the design of the

collaborative doctorate, but also in the findings of the first paper where the Swedish science park represented a potentially more systemically backed infrastructure for collaborative doctorate due to stronger culture for consensual communication of training needs within and between sectors. Put more concisely, systemic educational infrastructure tends to lead to the acquisition of "systemic skills", representing an emergent-tendency.

These findings have clear policy implications for higher education in general and doctoral education in particular. Going back to Smith's (1997) basic conceptualization, innovation systems can be seen as consisting of *infrastructures* and *institutions*, and the infrastructural part, which needs investment decisions, comprises of physical and knowledge infrastructures. He postulates that knowledge infrastructure is the central component of every national innovation system. Universities are deemed as *the* prominent part of the knowledge infrastructure, with production of knowledge as well as skills being part of their main roles. Smith argues that the most important policy issue around the knowledge infrastructure is coordination of government agencies dealing with different elements of this infrastructure. Accordingly, a key policy implication of the findings in this doctoral dissertation concerns coordination of entities and stakeholders (with the potential for) engaging in collaborative doctorate through regulatory means, an element to which in this dissertation is referred as a key *contextual mechanism*. A complementary message, then, is that such intervention should be made with a profound understanding of the way this mechanism will interact with the

disciplinary as well as organizational specificities of any concerned programme.

Kehm (2004) already identified the emerging tendency, around the turn of the century, to establish formal structures for doctoral education in the form of disciplinary or interdisciplinary programmes or graduate schools, instead of the traditional apprenticeship model of doctoral training. In other words, structures emanating from the disciplinary element have been increasingly overtaking, at least partially, the role of individual "agents" like doctoral supervisors in training of doctoral candidates. Now, the current research is advocating for the inclusion of contextual elements - such as industrial associations – too in shaping the organizational structures around doctoral education in order to make such structures potent enough in equipping doctoral candidates with generic skills sought in the non-academic career sectors. This call resonates, in a way, the recent work by Sharmini and Spronken-Smith (2020) who propose establishing a constructive alignment between learning *opportunities* and learning *outcomes* through provision of flexible, personalized portfolios for PhD candidates. In other words, disciplinary graduate schools need organizational enrichment through addition of intersectoral (transdisciplinary) educational sources, and this can be tailored according to the specific skills sought from individual doctoral candidates at the time of their graduation. Another similar example is the *doctoral design architecture* proposed by Coates *et al*. (2018). The authors who have prepared a report for the Australian government, use a three-phase doctoral education framework aiming at

ensuring doctoral education's contribution to contemporary career needs. The three phases include student outcomes, experiences, and preparations, together which constitute the structure for which certain codified functions can be pursued at the level of university and doctoral student at each phase. While such models can be seen as a step forward in establishing a logical connection between the diversified and flexible outcome pursued from doctoral education and the provision of respectively needed inputs and throughputs, they need to get enriched with deeper understanding of fundamental implications of epistemological attributes of academic disciplines. This is the area to which the current dissertation has strived to contribute to by giving the epistemic core of disciplines a prominent place in understanding, analyzing and designing of collaborative doctorate programmes.

As the concluding remark, I would like to make an analogy between what I would call it *discipline-based regimes of intersectoral collaboration* and technological innovation systems. After Carlsson *et al*. (1992) discussed technological systems identifiable around specific technology fields, Edquist (1997, p. 14) contended that "[…] it is probably easier to influence a technological system than a national system of innovation from the policy level". In a similar vein, Nelson and Rosenberg (1993) argued that the systems of institutions supporting technical innovations in one sector can be quite different from those supporting another sector. Likewise, I have tried to argue in this dissertation that higher education policies aiming at improving the employability of doctoral graduates in non-academic sectors should be designed at level of disciplinary groups

rather than being designed at the general level of doctoral education at the national (or any other geographical) level. This is due to the observation that different disciplinary groups are associable with different epistemic-social regimes, responding hence differently to the policy tools targeting their potential for intersectoral engagement facilitation. The importance of comprehending such discipline-based collaboration regimes becomes further paramount when considering that a comprehensive acquisition of generic skills is subject to their harmonic development with the disciplinary knowledge.

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Appendices

Appendix 1: Core questionnaires of the Paper I

Note: *The interviews conducted for Paper I research were of semi-structured type, hence the questionnaires presented in this appendix show only the core questionnaires used in the interviews. Other questions during some of the interviews have been added depending on the flow of information in the conversation, which can be provided upon request.*

A) Core questionnaire for interviews at the companies located in the science parks

1) Could you please start by presenting yourself, your company and your responsibilities?
2) Do you have any PhD candidates working at the company right now?
3) Do you need doctoral skills? What do you consider being doctoral skills?
4) Do you see any added value between someone having a doctoral degree or Master's degree, or between a doctoral student and a Master's student? Is the difference more on transversal skills, like autonomy, communication skills, ability to work in teams and so on, or on technical skills?
5) When you are looking for doctoral skills here in the company, how do you look for it?
6) Do you have any difficulty in finding the skills that you need?
7) When are you looking for new skills? And how far ahead can you know Usually? Can you project that in 6 months?
8) Do you usually proceed by networking to find the required skills?
9) Does your company have any relationships with the university regarding the skills? For example, do some of your staff give courses at the university?
10) Why did the founders of the company choose to locate the company in the Science Park?

11) Do you find any advantages of being a member of the Science Park regarding the search for skills?
12) What kind of relationships you have with the university adjacent to the Science Park? Does it include giving courses and collaborating on the research projects?
13) Has the university ever asked you for what kind of skills you would need? And you would like them to do so?
14) Would you look for Industrial PhDs in search of skills? Do you have a preference for hiring them?
15) If you had several candidates to choose in, would you have a local preference, someone who graduated from the university adjacent to the Science Park?

B) Core questionnaire for interviews at the universities located adjacent to the science parks

1) Could you please present yourself and your role in the university?
2) Is PhD education one priority in the development of research collaborations with companies?
3) How do you perform the collection of skills needs from different stakeholders of the society?
4) How will you deal with the evolution of the needs of companies over years? Have you planned to do updates of the generic competences program, for example by interviewing companies again?
5) Is participation of doctoral researchers in generic competences programmes compulsory or optional? Or is it different for different courses?
6) Have you found huge differences between disciplines in PhD education regarding transversal skills?
7) In hard science do you see a difference in participation in generic skills programmes between academic PhDs and Industrial PhDs?
8) Will there be an Industrial PhD programme rather than purely academic PhD programme at your university?
9) In what ways will you involve the main campus of the university as well as the big companies apart from funding? For

example will the companies be involved in the supervision of PhD candidates?

10) Will you try to create a kind of process (formal or informal) of anticipation of needs from the companies and then implication of the companies in the creation or update of PhD education offer or it will be more ad hoc?
11) Is there an added value of being part of the Science Park regarding the issue of PhD education?

C) Core questionnaire for interviews with the science parks' management

1) Could you please begin by presenting yourself and your section in the Science Park?
2) Does your unit select the companies who apply to come here, to become a member of the park?
3) What kind of support programs do you provide for companies?
4) Do you collaborate with the university with providing training in entrepreneurship?
5) What kind of stakeholders can be involved in PhD education and/or PhD recruitment in the Science park?
6) Is there a process (formal or informal) in the identification of needs for doctoral skills and PhD holder recruitment in the Science Park.
7) Has the Science Park any mission of dealing with recruitment of workforce for the Science Park, as an intermediary like spreading advertisement for jobs, job openings?

Appendix 2: Survey questionnaire used for data collections for Paper III and the quantitative part in Paper IV

Note: *The questionnaire provided here is the one customized for the case of University of Twente, as the options of the answer to question 6 had to change in case of each of the universities surveyed.*

1- In which country are you conducting your doctoral studies? (The country hosting your home university for the doctoral studies).

(1) ❑ Denmark

(2) ❑ Norway

(3) ❑ Sweden

(4) ❑ The Netherlands

2- What is the name of your university where you are enrolled for the doctoral studies?

(1) ❑ University of Aalborg

(2) ❑ University of Stavanger

(3) ❑ Linköping University

(4) ❑ University of Twente

(5) ❑ University of Gothenburg

3- Is spending some time in another university in the form of research stays (mobility) part of your plan in the doctoral studies?

Yes	**No**
(1) ❑	(2) ❑

4- Where is (are) the university(-ies) where you will spend your research stay(s) located?

(1) ❑ In the same country as my home university for doctoral studies.

(2) ❑ In an EU country (one of the 28 EU member states)*

(3) ❑ In a European but non-EU member country

(4) ❑ In a non-European country

* At the time of the running of this survey, the UK is still assumed as an EU member state.

5- How long will you spend on the research stay at the other university(-ies) during your doctoral studies?

(1) ❑ Less than or equal to 6 months

(2) ❑ More than 6 months

6- Which faculty and research department / discipline are you affiliated with?

(1) ❑ BMS Faculty - The Technology, Policy and Society Group (HTSR, CSTM, STEPS, CHEPS, PHIL)

(2) ❑ BMS Faculty - The Technology, Human and Institutional Behavior Group (PHT, PCRS, PA, CS)

(3) ❑ BMS Faculty - The Technology, Data-analytics and Decision-Support Group (CPE, OMD, ELAN, IST, OWK)

(4) ❑ BMS Faculty - The Hitech Business and Entrepreneurship Group (IEBIS, NIKOS, TMS, CMOB, HRM, F&A)

(5) ❑ ET Faculty - Biomechanical Engineering

(6) ❑ ET Faculty - Civil Engineering

(7) ❑ ET Faculty - Design, Production and Management

(8) ❑ ET Faculty - Mechanics of Solids, Surfaces and Systems

(9) ❑ ET Faculty - Thermal and Fluid Engineering

(10) ❑ EEMCS / EWI Faculty - Computer Science

(11) ❑ EEMCS / EWI Faculty - Electrical Engineering

(12) ❑ EEMCS / EWI Faculty - Applied Mathematics

(13) ❑ EEMCS / EWI Faculty - Interdiscipline Creative Technology

(14) ❑ TNW Faculty - Applied Nanophotonics

(15) ❑ TNW Faculty - Bioengineering Technologies

(16) ❑ TNW Faculty - Energy Materials and Systems

(17) ❑ TNW Faculty - Imaging and Diagnostics

(18) ❑ TNW Faculty - Membrane Science and Technology

(19) ❑ TNW Faculty - Nanoelectronic Materials and Thin Films
(20) ❑ TNW Faculty - Organic, Supramolecular and Polymer Chemistry
(21) ❑ TNW Faculty - Physics of Fluids
(22) ❑ TNW Faculty - Process and Catalysis Engineering
(23) ❑ TNW Faculty - Soft Matter
(24) ❑ TNW Faculty - Translational Physiology
(25) ❑ ITC Faculty - Department of Earth Observation Science
(26) ❑ ITC Faculty - Department of Earth Systems Analysis
(27) ❑ ITC Faculty - Department of Geo-information Processing
(28) ❑ ITC Faculty - Department of Natural Resources
(29) ❑ ITC Faculty - Department of Urban and Regional Planning and Geo-information Management
(30) ❑ ITC Faculty - Department of Water Resources

7- For how long is your doctoral programme planned (according to the original plan, i.e. without assuming the unforeseen extensions)?

(1) ❑ 2 years*
(2) ❑ 3 years
(3) ❑ 4 years
(4) ❑ 5 years
(5) ❑ 6 years

* 2 years would be the case of e.g. the PDEng studies in the Netherlands, or the Licentiate degree in Sweden.

8- When did you start your doctoral studies?

(1) ❑ 2010
(2) ❑ 2011
(3) ❑ 2012
(4) ❑ 2013

(5) ❑ 2014

(6) ❑ 2015

(7) ❑ 2016

(8) ❑ 2017

(9) ❑ 2018

(10) ❑ 2019

9- Which type of doctoral programme are you undertaking?

(1) ❑ Research doctorate with a monograph dissertation

(3) ❑ Ph.D. by publications in the form of journal articles

(4) ❑ Industrial doctorate

(2) ❑ Professional doctorate (title will be e.g. MD, EngD, EdD, DBA)

(12) ❑ Public-sector doctorate (found in e.g. Norway)

(11) ❑ Licentiate degree (found in Sweden)

(10) ❑ PDEng (found in the Netherlands)

(5) ❑ Taught doctorate (found esp. in the UK)

(6) ❑ Practice-based doctorate (found esp. in the UK)

(7) ❑ New-route doctorate (found in the UK)

(8) ❑ Joint doctorate (Doctorate offered by 2 or more universities)

(9) ❑ Cooperative doctorate (cooperation between a university and a university of applied sciences, found esp. in Germany)

(13) ❑ Other types

10- Is formal collaboration with non-academic public sector organisations in conducting research part of your PhD?

Yes	No
(1) ❑	(2) ❑

11- Is formal collaboration with private sector firms in conducting research part of your PhD?

Yes	No
(1) ❑	(2) ❑

12- Is the collaborating firm / organisation located in the same city or region* as your university?

(1) ❑ Yes, it is located in the same city.

(2) ❑ It is located outside the city of my university but within the same region.

(3) ❑ No, it is located outside the region.

* Being located in the same region here refers to being located at the same state governance unit just one level immediately below the national level.

13- How long will your collaboration with the non-academic partner last during the whole PhD education period?

(1) ❑ Less than or equal to 6 months.

(3) ❑ More than 6 months.

14- How long of the collaborative research will you physically spend at the collaborating entity's facilities (for how long will you be located there in total)?

(1) ❑ No time will be spent physically at the collaborating entity's facilities.

(2) ❑ Less than or equal to 6 months.

(3) ❑ More than 6 months but less than the whole period of the doctoral studies.

(4) ❑ The whole period of the doctoral studies.

15- Does the collaborating firm / organisation partially / fully fund the doctoral project?

(1) ❑ Yes

(2) ❑ No

16- To what extent the collaborating entity (e.g. a supervisor you might have there) influences the direction of your research thematically?

(1) ❑ No influence

(2) ❑ Little influence

(3) ❑ Significant influence

17- In your assessment, does the collaboration limit or slowdown the process of your doctoral research publications?

(1) ❑ It limits what I can publish.

(2) ❑ It slows down the process of publication.

(3) ❑ None of the above.

18- Has your collaboration with the collaborating firm / organisation already started?

Yes	**No**
(1) ❑	(2) ❑

19- How long of your collaboration with the firm / organisation has passed already?

(1) ❑ Less than or equal to 6 months.

(3) ❑ More than 6 months.

20- In your assessment, has the collaboration with the collaborating firm / organisation helped you acquire at least one of the transferable skills*?

(1) ❑ Yes, considerably

(2) ❑ Yes, a little

(3) ❑ No

* Transferable skills here refer to a set of skills acquired during the PhD education that can be used in the next career of the PhD candidate even in other type of work environments such as industry or public sector. Examples include: Communication and presentation skills, Project management skills, Team working skills, Networking skills, Managing data and

information technology, Self-management & work ethics, Analysis & problem-solving, Leadership and supervision skills, Research skills

21- In which of the following generic skills do you think you have improved due to the collaboration with the firms / organisations during your PhD education? (Please choose as many as applies to your case).

(1) ❑ Communication and presentation skills
(2) ❑ Project management skills
(3) ❑ Team working skills
(4) ❑ Networking skills
(5) ❑ Managing data and information technology
(6) ❑ Self-management & work ethics
(7) ❑ Analysis & problem-solving
(8) ❑ Leadership and supervision skills
(9) ❑ Research skills
(10) ❑ None

22- In your assessment, has the collaboration with the collaborating firm / organisation deepened your knowledge in your academic specialisation area?

(1) ❑ Yes, to a large extent
(2) ❑ Yes, somewhat
(3) ❑ No

23- In your assessment, has your PhD education within the university environment itself helped you in acquiring one or more of the transferable skills*?

(1) ❑ Yes, through some specifically dedicated course(s) for those specific skills.
(2) ❑ Yes, through my routine research, administrative and / or teaching activities.
(3) ❑ No

* Transferable skills here refer to a set of skills acquired during the PhD education that can be used in the next career of the PhD candidate even in other type of work environments such as industry or public sector. Examples include: Communication and presentation skills, Project management skills, Team working skills, Networking skills, Managing data and information technology, Self-management & work ethics, Analysis & problem-solving, Leadership and supervision skills, Research skills

Thank you very much for taking time to participate in this survey! Good luck!

Appendix 3: Core questionnaire of the qualitative part in Paper IV

Note: *The interviews conducted for Paper IV research were of semi-structured type, hence the questionnaire presented in this appendix show only the core questionnaires used in the interviews. Other questions during some of the interviews have been added depending on the flow of information in the conversation, which can be provided upon request.*

Core questionnaire for interviews with doctoral candidates at the two universities

1) What is your status as a PhD researcher? Are you employed by the university or another entity? How is your PhD financed?
2) Could you please elaborate on your affiliation to the departments in the university? Which unit are you affiliated with?
3) How is your PhD education organized? Under which graduate school etc.?
4) Are all doctoral researchers in your division using the same type of programme?
5) Is your collaboration with public / private organisations taking place in the country of destination for your mobility (in case mobility is part of your PhD)?
6) Can you elaborate on the type of your doctoral programme? Do you need to take certain courses and ECTS? Is it influenced by your academic discipline?
7) Can you elaborate on the collaboration with the public / private sector entity? Who are the key persons involved in the collaboration? Which branch / industry in the sector are you collaborating with?
8) Is the regional proximity important for this collaboration? What is your role and tasks at the external organization?
9) Would you have preferred a shorter / longer / more intense collaboration? Why? Does this relate to the impact of collaboration on your PhD performance?

10) What has been the role of your supervisor and the academic department you belong to in arranging the collaboration? What has been the role of your supervisor at the collaborating entity?
11) Can you elaborate on the way the collaboration has helped you in acquiring the transferable skills you have referred to in the survey? In which type of transferable skills you think you have improved more?
12) How would you think the process of acquiring transferable skills can be improved? Is the collaboration the best way for this? Would you prefer a formal training on these skills?

Paper I - IV

Paper I

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Aligning doctoral education with local industrial employers' needs: a comparative case study

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Aligning doctoral education with local industrial employers' needs: a comparative case study

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ABSTRACT

Doctoral education was primarily designed to answer the human resources needs of academia. However, nowadays, increasing numbers of doctorate holders seek employment outside academia. Accordingly, doctoral education can be one of the means by which universities take part in the development of industry in their regions. This study explores whether and how doctoral-level skills are being adapted to the needs of local industrial employers in two different contexts. Two research and science parks situated next to research-intensive universities in Sweden and Spain were chosen as cases for an exploratory and comparative study. In these parks, local industrial employers conduct R&D activities that make them potentially attractive destinations for doctoral graduates. Similarities in the cases were found regarding the process of adaptation of doctoral education at the adjacent universities to meet the industrial employers' needs in the parks. Discrepancies are also highlighted regarding stages of development, institutional settings, geography and culture. Implications for several stakeholders are formulated to improve the process analysed in the study concerning better alignment of doctoral education with industrial employers' need for generic skills.

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Doctoral education; science and technology parks; university–industry collaboration; generic skills; transferable skills

1. Introduction

The 2000 Lisbon Strategy demonstrated the intention of the European Union to support the development of a knowledge-based economy. Referring to this, Usher (2002) finds it a relevant question to ask whether the new mode of knowledge production in such economies implies the need for a new type of doctorate to provide graduates with the right skills for the knowledge economy. Consequently, he refers to the significance of 'human capital' in the knowledge economy, emphasizing that '[t]hose with much human capital are individuals with highly developed soft skills and the attainment of educational *qualifications* is not the only factor' (Usher, 2002, p. 3, emphasis in original). Accordingly, Usher finds the newer forms of doctoral education, such as professional doctorates and doctorates by

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project, as alternatives to PhDs by thesis, to better correspond to the skills required in the knowledge economy, because they bring academic and workplace training together.

In reality, some empirical findings highlight mismatches between non-academic employers' expectations and doctoral-level skills (De Grande, De Boyser, Vandevelde, & Van Rossem, 2010; Morgavi, McCarthy, & Metcalfe, 2007; Usher, 2002). University–industry collaborations can play a key role in addressing these mismatches (Roberts, 2018). Among the categories of organizational forms of university–industry collaboration, the establishment of 'focused structures', such as innovation centres or science and technology parks, entails the highest level of organizational involvement of a university in collaborating with industry (Ankrah & Al-Tabbaa, 2015). Through the analysis of two science and technology parks (STPs) situated near two research-intensive universities, in Sweden and Spain respectively, this paper aims to investigate whether the existence of these parks alongside universities can help to reduce the skills mismatch for doctoral researchers, and if so, how.

The research questions investigated in this exploratory study are: (a) Do the STPs currently contribute to doctoral education by facilitating various forms of university–industry interactions? (b) How do the STPs' specifics and configurations contribute to the build-up of doctoral-level skills? Exploring these issues will highlight the implications of the existence and specifics of STPs, for the better adaptation of doctoral education to the non-academic labour market.

The rest of this article is organized as follows: the next section reviews the literature about the labour market for doctorate holders and STPs. After that, the methodology adopted for this empirical study is described, and the findings of the case analyses are presented. A discussion on the comparison of these cases follows, and the article ends with a conclusion, in which contributions, policy implications, research limitations and suggestions for further research can be found.

2. Literature review

The number of doctoral graduates has steadily increased since 2000 across the OECD countries (Auriol, Misu, & Freeman, 2013). After graduation, most doctoral graduates who aspire to an academic career get temporary contracts, often postdoctoral positions. Postdocs' priority is to secure a tenure-track academic position (Sauermann & Roach, 2012). There are, however, few who succeed (Andalib, Ghaffarzadegan, & Larson, 2018; Etmanski, Walters, & Zarifa, 2017; Hendrix, 2014). Accordingly, the private sector is increasingly becoming a destination for doctorate holders, partly corresponding to the increase in private-sector R&D capacity (Bloch, Graversen, & Pedersen, 2015).

The qualifications acquired during doctoral studies do not necessarily correspond to employers' requirements. Important skills mismatches can be observed (CEDEFOP, 2016; Kulkarni, Lengnick-Hall, & Martinez, 2015). Overeducation[1] and overskilling[2] are closely correlated and lead to negative effects on earnings and job satisfaction for doctorate holders (Di Paolo & Mañé, 2016; Gaeta, Lubrano Lavadera, & Pastore, 2016). International mobility and self-employment are solutions for doctoral graduates to considerably reduce this mismatch (Ghosh & Grassi, 2017; Stenard & Sauermann, 2016). Indeed, countries that are developing their scientific and academic systems lack doctorate holders in many sectors of activity (Santos, Horta, & Heitor, 2016). The private sector also needs to be able to absorb the capabilities of the doctoral workforce; hiring doctoral graduates

enables firms to access scientific knowledge (Garcia-Quevedo, Mas-Verdú, & Polo-Otero, 2012; Herrera & Nieto, 2013; Lanciano-Morandat & Nohara, 2002). Mismatches are also due to the individual characteristics of doctorate holders (Roach & Sauermann, 2010; 2017), which evolve during doctoral studies: for example, due to their frequently decreasing interest in academic careers. Supporting doctoral students in discovering career opportunities (Thiry, Laursen, & Loshbaugh, 2015) and experiencing inter-sectoral mobility (Assbring & Nuur, 2017; Bienkowska & Klofsten, 2012; Roberts, 2018; Thune, 2010) should be more systematically integrated into doctoral education.

Manathunga, Pitt, and Critchley (2009) highlight the diversity of sectors in which doctoral graduates can find employment, and show that this implies a corresponding diversity of required skills. Accordingly, the authors emphasize the need to track doctoral graduates' employment destinations in order to make it possible for universities to more effectively produce employment-ready graduates. New forms of doctoral education have emerged with more relevance, linking university and industry more systemically: for example, the professional doctorate (Benito & Romera, 2013). Industry-based doctoral study programmes give doctoral researchers a more positive orientation towards working with industry (Harman, 2004) and industry funding can enhance their career prospects (Harman, 2002). Such programmes can also give graduates a more nuanced understanding of the different skills required in each employment sector (Manathunga et al., 2009). The skills required of doctoral students differ across countries (Matas, 2012) and within the same country (Nerad, 2015). For instance, sometimes a professional qualification or experience is required to enter a professional doctorate programme. Thus, skills development plans differ among doctoral programmes.

Some scholars consider that doctoral students should be regarded as research professionals (Gokhberg, Meissner, & Shmatko, 2017). However, the wide range of career opportunities for doctoral graduates increases the importance of skills that extend beyond the core research skills (Bienkowska & Klofsten, 2012). Such skills are called transferable, transversal, or generic. Most of these are usable across both research-intensive and non-research-intensive careers (Kyvik & Olsen, 2012; Sinche et al., 2017). Such skills can be acquired through formal training, an organized and systematic training explicitly aiming to build transferable skills; informal training, through everyday activities or regular academic classes; or formally organized informal training, workplace experience programmes such as industrial PhDs, internships and exchanges (OECD, 2012; see also Drummond, Nixon, & Wiltshire, 1998). Looking at the factors influencing the initial job attainment following completion of a PhD programme, Jackson and Michelson (2015) propose integrating work placement into course design or encouraging part-time paid employment during PhD studies. Their study shows that strong integration into the *research community* is an important predictor of initial job attainment for PhD graduates.

In line with this view, we aim to explore whether the existence of STPs adjacent to research-intensive universities helps to facilitate the transition to a post-PhD career. Indeed, the literature on interorganisational learning identifies different types of distances that can lead to incompatibilities and prevent successful collaborations as primary challenges: organizational, social, institutional, geographical, and cognitive distances; in other words, a lack of the corresponding proximities (Boschma, 2005). Boschma (2005, p. 71) makes it clear that, in theory, 'geographical proximity, combined with some level of cognitive proximity, is sufficient for interactive learning to take place'. In addition,

acquiring transferable skills aims to overcome the cognitive distance that significantly hinders the frequency of university–industry (UI) interactions (Muscio & Pozzali, 2013; Revilla Diez, 2000). Thus, STPs might contribute to the build-up of transferable skills during doctoral education. In their systematic review of the UI collaborations literature, Ankrah and Al-Tabbaa (2015) highlight the shortage of studies on the consequences of engagement with industry for the learning experience of students. While STPs represent the highest level of organized UI interactions, the potential benefit of their existence in the vicinity of universities for the skills acquisition of doctoral researchers, and consequently for their careers, has not been explored in the literature. Our paper, therefore, aims to close these gaps in the literature by studying whether STPs contribute to doctoral education at the adjacent universities.

In the present study, the generic term 'STPs' is used to designate different types of science and technology parks. However, the variety of STPs should not be overlooked. Almeida, Santos, and Rui Silva (2009) distinguished different types of parks depending on their science-intensiveness (focus on invention) on the one hand, and their business-intensiveness (focus on innovation) on the other. Their typology distinguishes R&D-intensive parks, technology parks, innovation parks, and business parks. Albahari, Pérez-Canto, Barge-Gil, and Modrego (2017) also studied the heterogeneity of STPs according to the degree of university involvement in these parks. No matter what the type of STPs, for tenant firms, the main means of obtaining knowledge from universities is maintaining 'long-term' relationships via both formal and informal interactions (Díez-Vial & Montoro-Sánchez, 2016). In particular, Hu (2008) demonstrates the importance of high-tech talent mobility and informal relationships for innovation performance during the various stages of science-park development.

3. Method and data

Our choice of the case study method is justified by the aim of exploring contemporary events (Yin, 1984). In addition, Yin recommends this method to answer 'how' research questions, like ours. Studying two cases is justified by the desire to explore different context specificities (in particular, different types of parks), to suggest implications for more than one case and potentially apply them to other, similar cases as well. In order to conduct the comparative study, the following criteria were applied when selecting the cases:

(a) Parks and their tenants should be physically situated next to a research-intensive university and have established relationships with the university.
(b) Park tenants' activities should be related to STEM (Science, Technology, Engineering and Mathematics) disciplines.[3]
(c) Cases should be heterogeneous; in particular, they should be embedded within different cultural and institutional settings.

This study focuses on two cases of park–university relations. Södertälje Science Park (SSCP), in Sweden, was established in 2016 on the outskirts of Stockholm, while, in Spain, the Research Park of the Autonomous University of Barcelona (henceforth UAB), called PRUAB (UAB Parc de Recerca), was established in 2007 on the outskirts of Barcelona. They were chosen, firstly, because of their strong links with nearby

research-intensive universities (UAB and KTH). In line with criterion (a), the SSCP is quite new and is developing along with the campus of the Royal Institute of Technology (henceforth KTH) in Södertälje thanks to the close cooperation between the KTH and the multinational firms based there; while PRUAB is an entity of the university itself and is a strong actor on the campus. In addition, park tenants' activities are coherent with criterion (b): in the SSCP, biomedical and automotive industries are strongly represented; while in PRUAB, ICT and biomedicine predominate. Finally, the cases were chosen because comparable organizational choices were made (research and science parks in interaction with a nearby university), but also because they are situated in regions that differ both culturally and institutionally, in line with criterion (c). Both the SSCP and PRUAB also showed interest in taking part in the RUNIN[4] project.

Data was collected through 17 semi-structured face-to-face interviews between September 2017 and January 2018. The aim was to recruit interviewees from universities, private companies, and all other actors potentially involved in doctoral education or the recruitment of doctorate holders. Members of the university management and employers from the SSCP and PRUAB were contacted as a priority. All interviewees have positions of responsibility in their respective organizations: they are CEOs, project managers, and heads of divisions or departments. Appendix 1 provides an overview of the interviews. Appendix 2 provides an anonymised list of interviewees and their corresponding organizations.

The methodology developed by Gioia, Corley, and Hamilton (2013) and the NVivo software were chosen for the analysis. Inspired by Glaser and Strauss's (1967) grounded theory and designed for exploratory studies, it starts from the informants' discourses in order to minimize the bias researchers may bring from theory and to foster the creation of new concepts. The method consists of three steps of analysis (see Table 1). Charts were built to visualize the results of our application of the chosen methodology to the cases in the different steps, facilitating the identification of their similarities (Figure 1), as well as their respective strengths and weaknesses (Figures 2 and 3).

Table 1. Overview of the methodology developed in Gioia et al. (2013) applied to the cases.

	1st order analysis	2nd order analysis	3rd order analysis
Aim	Coding from the informants' discourses	Structuring the 1st order coding into themes	Structuring the 2nd order coding into aggregate dimensions
Number of iterations	3	3	2
Final number of:	Nodes	Themes	Aggregate dimensions
For PRUAB case:	34	12	4
For SSCP case:	58	12	4

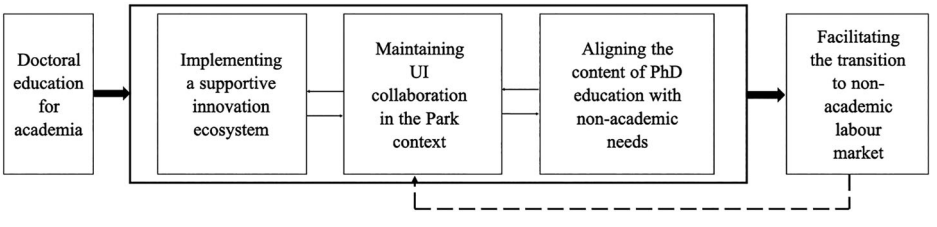

Figure 1. An analytical model of the process of adapting doctoral education to the needs of non-academic employers in both parks.

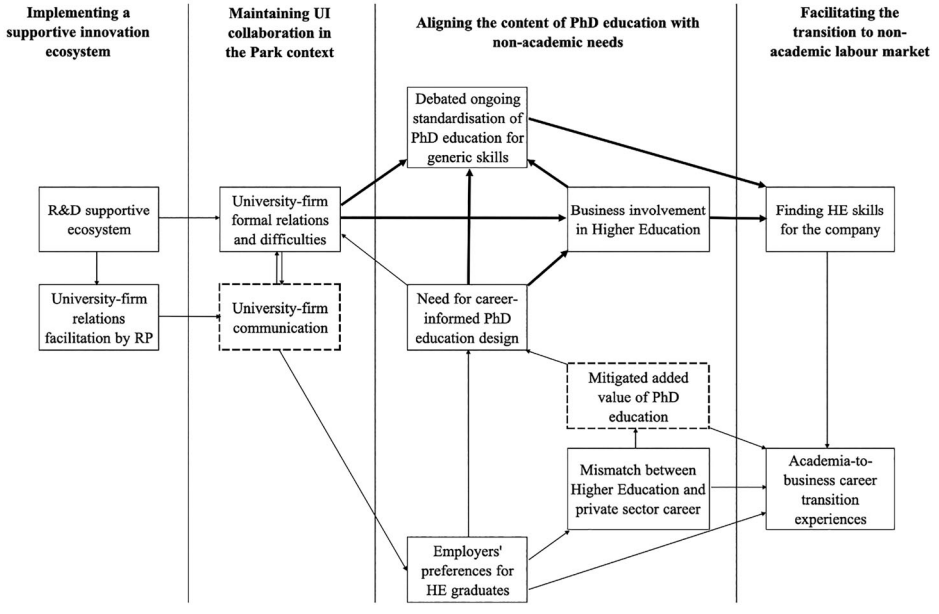

Figure 2. The process of providing doctoral-level skills in PRUAB. Squares with dashed outlines represent weaknesses. Bold arrows represent strengths.

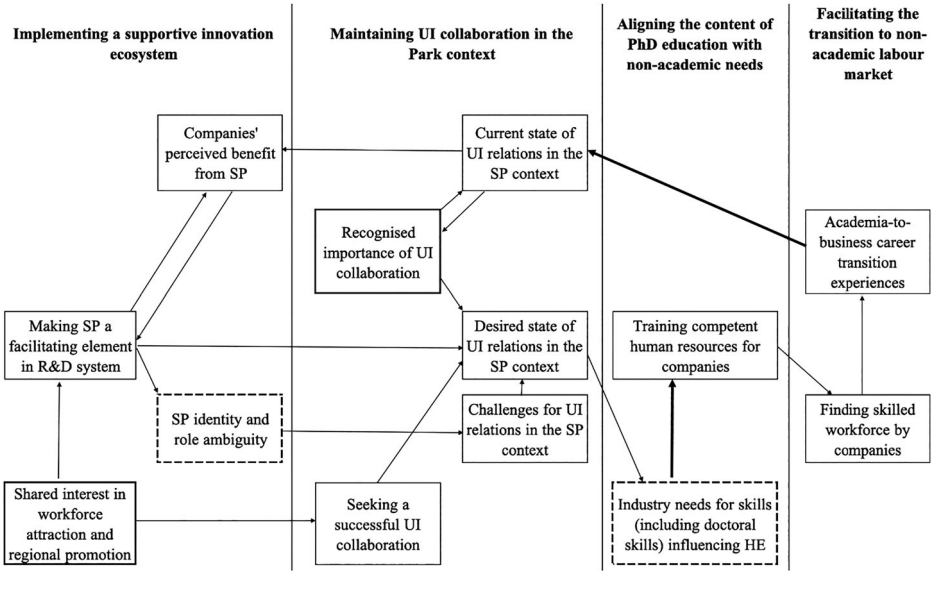

Figure 3. The process of providing doctoral-level skills in the SSCP. Squares with dashed outlines represent weaknesses. Bold squares and arrows represent strengths.

4. Findings

The implementation of this methodology led to a comparison of the cases. However, the thematic content and themes' configurations differ, reflecting the underlying heterogeneity of the SPs.

4.1. Similar processes in the SSCP and PRUAB

Despite their differences, identical aggregate dimensions were found in both cases. These dimensions follow a logical sequential order, making it possible to consider them as steps in a process of provision of doctoral-level skills to the parks. This process is represented in the form of an analytical model in Figure 2, and takes the following point of departure for input: doctoral education is designed for academia. The output is the effect of adapting doctoral education for both academic and non-academic careers, corresponding to the dimension 'facilitating the transition to a non-academic labour market' for doctorate holders. The process is composed of three other dimensions: 'implementing a supportive innovation ecosystem' through the creation of STPs, 'maintaining UI collaboration in the park context', and 'aligning the content of doctoral education with non-academic needs'. However, the process can also be self-reinforcing since, ideally, each step reinforces the previous one. If the content of doctoral education is aligned with non-academic needs, then UI collaboration is more likely to be sustained. If this collaboration is sustainable, then stakeholders will perceive the benefit of being part of the park, enabling increasing support for the existence of the park and increasing resources. Also, if the process results in facilitating the transition to a non-academic labour market for doctorate holders, then doctoral graduates working in industry in the park are likely to maintain relationships with the university, thus reinforcing the process by encouraging the maintenance of UI collaboration in the context of the park. This is in line with Ferru's (2014) findings that most UI collaborations are renewed rather than built from scratch.

4.2. The case of PRUAB

The UAB (Autonomous University of Barcelona) has its main campus on the outskirts of Barcelona: the Campus of International Excellence hosting research centres, e.g. the Centre for Research in Agricultural Genomics (CRAG), and PRUAB, created by the university in 2007 to 'promote and enhance the technology and knowledge transfer activities of its members, encourage entrepreneurship through the creation of new businesses based on research, and generally facilitate interaction between research, business, and society' (PRUAB, 2018). PRUAB companies' fields of activity are mainly Information and Communications Technologies (ICT) and biomedicine. PRUAB's board is composed of members of the university as well as research centres, such as the Institute of Agri-food Research and Technology (IRTA) and the Spanish National Research Council (CSIC).

4.2.1. Implementing a supportive innovation ecosystem

One overall dimension emerging from the interviews is the importance of an environment that supports companies' innovation activities. Some interviewees highlighted the

advantages of establishing their business in Barcelona, citing the tax incentives for research activities and the presence of high-quality universities:

> Spain was a good country, good choice, because it has many good universities, and also there are tax advantages, and then we knew Barcelona was a good fit, has some good universities, there's many companies nearby (Interviewee K).

However, when contrasted with some other advanced environments, such as the USA, Spain as a whole is considered to be an environment less favourable to the 'development' that follows 'research' in R&D. The supportive ecosystem is thus important, even more so as SPs host start-ups with limited resources. The maturity of supportive mechanisms is an important issue. For some, PRUAB has 'a lack of experience . . . it's quite new, it's 10 years old' (Interviewee L). Nevertheless, PRUAB's tenants perceive benefits from residing there, such as the infrastructure, partnerships in European projects, consultancy and incubation services, and the contact opportunities with the university and with other tenants due to geographical proximity. Some tenants use the university's labs or have the university as their customer. However, PRUAB staff listed more advantages and services, such as training courses on entrepreneurship, idea-generation programmes, and programmes to generate multi-disciplinary teams (Interviewee J), which (surprisingly) were not always mentioned by tenant interviewees.

4.2.2. Maintaining UI collaboration in the park context

PRUAB's tenants and the UAB engage in both informal and formal interactions. According to the UAB, the establishment of PRUAB was meant to serve the purpose of facilitating such relationships: 'We're using the research park as a tool to have relationships with the companies' (Interviewee I). Formal relations themselves also materialize in various formats. 'We have designated professors who help us, they're part of our concept to take care of helping the research to take the right direction' (Interviewee K). Establishing spin-offs, hiring postdocs and master's students, collaborating within the framework of European projects, and university–company staff mobility are some of the formal interactions mentioned. However, collaborating with doctoral students appears to be less prevalent among PRUAB's tenants. The most cited reason is the faster pace of firms' research activities compared to those of doctoral projects. A lack of resources is another obstacle for university–firm collaboration in the park context: 'Yes, we've had [collaboration with the UAB] and I know how to do it, I'm just waiting to get funding to do it again because we always learn something' (Interviewee M). Public–private conflicts of interest appeared to be another major issue acting against university–firm collaboration: in the university's choice of a company to implement a technology transfer, in companies' use of university facilities, in intellectual property rights issues, or in ownership of companies by university staff.

Informal interactions and communications between the university and park-based firms constitute important precursors to formal interactions. Nevertheless, these communications do not happen at the same level across all university departments:

> For example, the engineering school here at the UAB, it's very close to companies so it's easier for them to have a meeting with the companies and with the researchers to put in common what are the needs, but with others it's really difficult because they're not so much in contact (Interviewee I).

Moreover, many of PRUAB's tenants think that communication with the university could be improved: 'there's no process for feedback to the university professors' (Interviewee M); ' … it would be very interesting to have more cooperation among the different actors in the economy when doing PhD research, so being more linked with the real world' (Interviewee Q).

4.2.3. Aligning the content of doctoral education with non-academic needs

Most of the companies wish for closer cooperation and communication with universities, recognizing a mismatch between the skills provided by the higher education system and those needed in business-sector careers. More specifically, knowledge and understanding of customer needs is deemed crucial for creating a new product that will be successful in the market. This is valid for doctoral graduates, too, as many of them will be employed outside academia. The lack of management and business skills was specifically highlighted by interviewees:

> To have people well trained from the technical point of view is nice, but the careers of those people are short. Why? Because when the product is developed, it's finished; then, we need to sell that product and to improve that product, and to improve a product is not the same as to develop a product (Interviewee P).

Some employers in PRUAB clearly stated their preference for master's graduates because they perceive them as more open and flexible to the multi-disciplinary work that is essential to the business environment.

There is a belief in the need for change in the design of doctoral education among some business leaders. However, the research-related skills acquired during doctoral education are appreciated by companies, even more than a knowledge of the specific scientific field:

> Having a PhD, in a sense, is like a certification, you know, that you have that kind of experience, that you had to deal with this kind of ability to manage a problem, so in this sense, it's an added value (Interviewee N); 'It's more the skills of organising the work, of learning, of synthesising complex ideas that are very valuable' (Interviewee Q).

The industrial doctoral programme seems preferable to some non-academic employers: 'I like the industrial PhD … because you're learning a very important thing, which is management, real management' (Interviewee L). The need for such transversal or transferable skills has been considered by the university. UAB's doctoral school recently developed the Professional Competence Model for UAB researchers. It includes the competences needed for doctoral students in six domains ' … the first is interpersonal skills, the second is cognitive skills, then communication, research skills, organizational skills, and influencing and impacting skills' (Interviewee I). These skills are now taught to doctoral students across the university in the form of either mandatory or optional courses. Nevertheless, heterogeneity remains among departments and doctoral programmes within the university.

4.2.4. Facilitating the transition to the non-academic labour market

One of the advantages of being in the park that is described by PRUAB's tenants is their access to human resources due to the university's proximity. However, companies do not all follow the same path in finding skills. Hiring from the local university is not necessarily

a priority for all companies: 'I want talent, I don't care where the talent comes from' (Interviewee L). This interviewee uses both local and professional social networks to recruit doctorate holders. Participation in the training of master's students is another way for some tenants to find a potential doctoral student with whom to collaborate. Proximity to the university, the implied networking possibilities and agility in the hiring process are considered advantages:

> . . . if necessary, next week we could be 20 people instead of four, I could call professors I know personally: Who's good in your classroom? Who's good in that field? Who's good in that? That's very important. Yes, I know there are the human resources companies, of course, but here it's faster (Interviewee M).

In parallel, the preferences of graduates also need to be considered, such as a preference for stability:

> To acquire an academic career in Spain or in Catalonia, you need to have been abroad for at least two years … but yes, the economic situation made it kind of difficult to imagine that once you had been abroad for two years there could be any opportunity for coming back (Interviewee Q);

> When you finish your PhD, you get to a point in life when you want some stability, you want to start a family, for example, or you want to be able to buy a house, and with research in a university, it's impossible to know that, so you work on a grant that will finish in two years, and after those two years, if your PI [Principal Investigator] doesn't have another grant, then you're out, so you have the same feeling as when you finished your degree at the university: And now what? You have that feeling constantly, every two years' (Interviewee O).

4.3. The SSCP case

Södertälje is situated 50 km outside of Stockholm and is thus considered to be part of the suburbs of the capital. The city has been welcoming diverse immigrant populations for the past century. It also hosts large production sites for multinational companies (approximately 20,000 employees) and is known for its success in organic food production. KTH, a highly ranked Swedish engineering school, has a small campus in Södertälje. Through this campus, the close links that KTH already had with a multinational company with a production site in the city were strengthened. These two closely related actors initiated the creation of the SP in 2016. However, this idea of creating an SP, supported by the municipality and other private actors in the area, was triggered by a particular event: the closure of the large R&D site of another multinational company, with only a small part of its activities being relocated to a different Swedish region, which caused many redundancies and the risk of a damaged image for Södertälje. The SP aims to promote Södertälje and attract economic actors and an additional workforce by branding itself as a knowledge city and by excelling in sustainable production in diverse industries.

4.3.1. Implementing a supportive innovation ecosystem

The history of the newly created SP in Södertälje is marked by an interest in promoting the city's image. This interest is shared by the different stakeholders: the municipality, the university, and private companies; in particular, the largest ones. This consensus is a strength of the ecosystem: Sharing a common goal makes it easier to share the same vision and to

find consensus. The aim is to make the city and its surroundings an increasingly attractive place in which to both work and live: 'You can study and work in Södertälje … we need to show the possibilities of Södertälje' (Interviewee C). According to these actors, making Södertälje recognized for its specificities, such as being a place for innovative industry through a focus on sustainable production, will enable such attraction. The creation of the SSCP is thus a means for stakeholders to structure the R&D system in Södertälje and attract companies and a workforce:

> This is a way of using the parties in the science park to sort of lift Södertälje and lift all the companies in Södertälje, showing that Södertälje could be a knowledge society instead of being an area for refugees (Interviewee C).

All the stakeholders, and in particular private companies, seem to expect the SP to be a facilitating element in the ecosystem:

> … an enabler where we can do things, where we can kind of accelerate ideas, also working together with [another private company] and other partners, and to really make the Södertälje brand stronger (Interviewee E).

This is a virtuous circle: The more they perceive this as a benefit, the more the SP will be able to act as a facilitating element. However, stakeholders have many additional expectations of the SSCP, which itself seems to have a varied list of missions: 'It's a meeting place' (Interviewee C), 'an arena where private firms and academia can discuss things' (Interviewee A); it's 'an innovative place or […] innovative atmosphere' (Interviewee D). The lack of a precise or targeted role for the SP can be perceived and is sometimes explicitly expressed: 'Where does the science park fit in, into the context?' (Interviewee B). Even the identity of the park is difficult to grasp since its board is composed of varied members of the public and private sectors and of academia. This ambiguity in the identity and role of the SP can be a weakness to the extent that, without more clarity, the stakeholders might not know how to make use of it or may not wish to do so: 'If the science park was not there, I would still do it [collaborate with the university]' (Interviewee G).

4.3.2. Maintaining UI collaboration in the park context

Even though UI collaboration has already happened and still occurs outside the framework of the SP in Södertälje ('there is such a strong relationship between KTH and Scania' [Interviewee C]), one of the main aims of the SP is to foster UI collaboration. Here again, a consensus can be observed regarding the importance of UI collaboration, which is recognized by all stakeholders. This is a strength that both feeds the current UI relations occurring in the context of the SP and is fed by them. Despite their recent emergence, current UI relations in the context of the SP are satisfactory and look promising: Strategic partnerships already exist ('there are different reference groups, steering groups with industry involved' [Interviewee B]) as well as industry sponsorship ('these [professorships] are important for us so […] we're paying for two of those professorships in cash' [Interviewee E]). This reinforces the perception of benefits accruing from the SP by stakeholders, even though the SP organization itself does not have any direct involvement in many of these collaborations. A successful UI collaboration is sought by the stakeholders because it is considered to be a key factor for the success of regional attraction

and promotion: 'It's all about having a good collaboration with the universities, I think that's the key' (Interviewee F). What is also striking in the case of the SSCP is that all the stakeholders express a vision of the future for their own organizations and for the SP. They all suggest their own insights into a desired state of UI relations in the context of the SP: sharing facilities, developing strategic partnerships, and constructing a research and education environment, including involvement from industry. This is due not only to the existing consensuses but also to the recognition of challenges raised by the SP's identity and role ambiguity, e.g. the challenge of communication. On the university's side: 'We need to make sure that we can communicate new knowledge all the time, continuously' (Interviewee B). On industry's side: 'One of my working areas is contact, dialogue with the universities' (Interviewee F).

4.3.3. Aligning the content of doctoral education with non-academic needs

Regarding doctoral education and doctoral-level skills, both the current and desired state of UI relations in the SP context mainly deal with the issue of industry's needs influencing higher education. Competence is crucial for industry, including at the doctoral level:

> We need these really scientific strong people who can handle very complex questions and also analyse them in an analytical way, and we also need to ensure that universities continuously start supplying us with the good researchers and that they're building up new state-of-the-art knowledge technologies and so on (Interviewee E).

The identification of industry's need for skills and the communication of these to the providers of education, namely, the local university, is being developed. SMEs[5] find such anticipation difficult, but established companies can do it. One multinational company has conducted an in-depth study, resulting in a roadmap covering the next 20 years that enables the anticipation of the need for particular skills. Communication of the need for skills is, however, ad hoc and specific to each organization whenever it is done. Working on this issue is a strength because it enables the training of competent human resources by the local university on behalf of the regional companies, where students are 'a recruitment base for the future' for these companies (Interviewee F). However, the fact that the great majority of these efforts are targeted at undergraduate education is a weakness, considering the focus of this study.

4.3.4. Facilitating the transition to a non-academic labour market

Thus, regional private companies can spot and hire doctorate recipients from the local university. These graduates might have relevant skills that can answer the needs of the hiring company. For companies, especially SMEs, 'the key is to find the right person' (Interviewee H), which is all the more important as they do not have the means to train a junior workforce:

> I think that maybe [a multinational company], if they employ one [junior], they can employ straight from the university, it's good they have fresh new knowledge and basic knowledge and they're easy to form, they're easy to adapt to a new environment, but if you have the small companies that don't have time to train someone for two years before they start producing so … it's a big risk, they need some experience (Interviewee G).

Hiring from the local university enables more frequent, easier, and better matching transitions from academia to the business world for doctorate recipients, who are needed in the

doctorate-holders' labour market. Such transitions are also a strength for the system because they reinforce the UI relationships in the STP context. Currently, many individuals (five of our interviewees) involved in the park from the various stakeholders are doctorate recipients.

5. Discussion

In both of our case studies, interviewees recognize a need for more relevance to industry within doctoral education, and, in line with that, a need for greater involvement of non-academic employers in the process of doctoral education. In fact, what stands out from the interviews is that, although they need employees with doctoral-level skills, most non-academic employers in the parks would rather invest in the recruitment and additional training of a master's graduate over a doctorate holder because master's graduates are perceived to be more adaptable, and thus easier and cheaper to train to be ready to work in the company. Nevertheless, initiatives to bring more relevance into doctoral education can be observed in both cases, although they vary in their degree of formalization. This enables us to compare the cases: for example, the 'Professional Competence Model for UAB Researchers' is quite formalized, while on the KTH campus in Södertälje, doctoral education is not yet in place. In the following, we discuss the two cases in terms of this paper's research questions.

5.1. The indirect contribution of STPs to doctoral education

The STPs do not really contribute to doctoral education, at least not directly. Indeed, the respective missions of the parks do not explicitly mention doctoral education, or even the provision of human resources to park tenants. Park missions do, however, entail UI collaboration, through knowledge transfer in one case, and for municipality branding in the other. The interviews show that doctoral education is clearly not seen as a priority by most of the stakeholders, and is sometimes not even thought of. However, the geographical proximity implied in the study of these parks might enable the potential for them to contribute indirectly to doctoral education, by supporting the development of a cognitive proximity between local industrial employers and the university in such areas as applied research and business skills.

The interviews provide enough information for us to visualize the processes of adaptation of doctoral education to industrial employers' needs (see Figure 2). The parks' two main contributions are: to enable and support different kinds of collaboration, preferably long term, between the tenant firms and the nearby university; and to encourage the launching of entrepreneurial ventures. In the case of PRUAB, collaborating with entities situated on campus (including the university) is actually a condition for being accepted as a tenant. The parks can be meeting places for tenants to meet university students and researchers: in both cases, they are situated within the university's campus (in the SSCP, the park and the university actually share buildings). Encouraging meetings between park tenants and university students and faculty is crucial in order to overcome geographical and cognitive distances, and transform them into proximities. In other words, the geographical proximity which characterizes the parks in both cases can enable the reduction of cognitive distance, by providing opportunities for the academic

and industrial parties to communicate, and to get to know each other's needs. Getting to meet can provide stakeholders with occasions for developing relationships and research-related collaborations, through both formal and informal contacts and exchanges of information. Among them, the need for doctoral-level skills can be discussed between the partners, as well as possibilities for non-academic partners to become involved in doctoral education in order to enhance the employability of doctorate holders. However, this indirect contribution to doctoral education is identical in the two parks: Figures 2 and 3 enable us to visualize and compare the processes in each case, and to identify different strengths and weaknesses, which are analysed below.

5.2. Influence of the parks' configurations

Referring to Almeida et al. (2009) and Albahari et al. (2017), it can be argued that the two cases correspond to different types of parks, because of the differing extent and form of the involvement of the respective universities in the ownership and operation of the parks. PRUAB actually stems from the UAB and is more oriented towards research, while the SSCP is a joint initiative of the university, the municipality and large companies, and is more oriented towards product and service development.

This difference in stakeholder configurations explains the differences in strengths and weaknesses identified in each case. On the one hand, in PRUAB, despite the UI geographical proximity, there seems to be little communication, at least regarding skills, and particularly doctoral-level skills. Thus, many employers in PRUAB do not consider a doctoral degree to be any more valuable than a master's degree in terms of employability, which is also linked to an existing mismatch between the expectations of employers and the doctoral-level skills acquired in universities. The strength of the case lies in the initiative of the university to create a framework of generic skills to be taught within doctoral programmes, with contributions from private companies in curriculum design. On the other hand, in the SSCP, the weaknesses lie in the absence of a clear definition of the role of the science park, which might discourage stakeholders from using what it offers, and the fact that industry involvement in higher education is largely focused on undergraduate education, overlooking doctoral programmes. However, in the undergraduate education, there is a combined effort by universities and major companies to train competent human resources for the companies. Moreover, many of the people who play a key role in the current UI relationships in the SSCP, which rely on the cognitive proximity existing between stakeholders regarding the need for regional promotion, the necessity of an STP, and the importance of UI collaboration, are actually doctorate holders themselves.

5.3. Influence of the cases' strengths and weaknesses

The different strengths and weaknesses of the parks also have different consequences for their potential to adapt doctoral education to the needs of non-academic employers. On the one hand, in the case of UAB, training in some generic skills is formalized in the shape of mandatory courses for all doctoral students. This was implemented after a consultation with employers from the private sector. Employers in PRUAB are small: most of them are SMEs, and the larger companies have a presence in the form of small units, such as a small laboratory. They might not themselves have the means, in terms of human and

financial resources, to invest in training recently graduated doctorate holders. It seems that the companies delegate this complementary training to create ready-to-work graduates to the university. The training in generic skills is thus more theoretical, and in the hands of the university. In addition, the majority of park tenants are oriented towards research, which is what doctoral students are trained for. Thus, the university can logically include the teaching of the skills they will need in the curricula for doctoral education. On the other hand, the SSCP is home to larger companies, which are very active and have the capacity to invest both in the university by taking part in teaching, and within their own organization by hiring industrial doctoral students. Companies are more legitimate entities to provide what can be seen as more practical training that the doctoral students and doctorate holders might lack, since product or service development is their core activity. In summary, we can distinguish between the theoretical and practical training through which industrial employers influence doctoral education, so that doctorate holders acquire the skills these employers need. The theoretical training in generic skills complements the research education and is provided within the university, while the practical training for those skills is provided within the companies to convey training on product or service development. This is a natural distinction resulting from the configurations of the parks, both in terms of activities (research vs. development) and company structure (SMEs vs. large companies). Nevertheless, both types of training are relevant and important for doctoral education, to develop the right skills and the means for doctorate holders to find a relevant job outside academia.

5.4. Geographical and cognitive proximities

The parks present some contrasting functions in their respective settings. Figures 2 and 3 depict differences in the configuration of themes which emerge from the interviews within each case. In general, in the case of PRUAB, the university and the park are both well-established, but their collaboration related to higher education has not yet matured. Indeed, in Figure 3, the aggregate dimension related to implementing a supportive innovation ecosystem is thematically less rich, while the one related to aligning the content of doctoral education with non-academic needs is thematically more elaborate. On the other hand, considering the same aggregate dimensions for the SSCP, the culture of collaboration between the university and the park firms is already strong, while the respective support organizations and campus-based doctoral education are still not fully developed.

Accordingly, there seems to be a paradox; in the SSCP, a strong cognitive proximity causes the various stakeholders (in particular, the university and large companies) to be aligned; at the same time, large companies have the means to invest in education and take responsibility for part of it. This means that, theoretically, they have enough influence to make their voices stronger and their interest weigh more in this context. In addition, tenants of the Science Park are all geographically situated within the municipality of Södertälje, but spread across it. In PRUAB, a comparable level of cognitive proximity is not observable. The companies seem to delegate their responsibility for taking part in education – so that it answers their needs in a more relevant way – to the university: this logically should lead to more communication and greater alignment between the employers and the university, which should be facilitated by the large majority of companies being geographically concentrated within a couple of buildings on campus. One reason for such a paradox

could be the difference between the two parks' representativeness of the total pool of local research-intensive employers: in the SSCP, tenants might represent a majority of the pool, considering the number of industrial employers in Södertälje and its suburbs, while in PRUAB, the tenants might only represent a small share of the pool, considering the number of employers in Barcelona and its suburbs. This shows that, in the case of PRUAB, the geographical proximity is in fact underexploited and could be better used to develop a cognitive proximity between industrial employers and the university.

6. Conclusion

This study contributes to the literature on process-oriented studies of Science and Technology Parks (Autio & Klofsten, 1998) and to the literature on doctoral education and the careers of doctorate holders, by exploring the contribution of STPs and their tenants to doctoral education. To the best of our knowledge, this is the first attempt in the literature to study the actual and potential role that STPs can play in the career-preparedness of doctoral students.

These findings have theoretical implications: *intrasectoral* collaboration and communication (e.g. within the university and within the business community) have positive consequences for *intersectoral* linkages and interactions because they smooth the process of reaching consensus within each sector. The findings from the SSCP case show that a well-functioning intrasectoral collaboration and common language can bring about the necessary preconditions for the establishment of cognitive proximity between the heterogeneous sectors.

Our findings also carry several implications for universities, industrial employers, and regional policymakers. In particular, the following recommendations might support the contribution of STPs to the build-up of doctoral-level skills. A more systematic anticipation of the need for particular skills by industrial employers, and the communication of these needs to universities through the creation of discussion spaces, such as forums on skills, would enable the universities to consider these needs in doctoral education curricula. The creation, communication, and support of opportunities for intersectoral mobility, e.g. through short-term industrial experience during doctoral education (in line with Etmanski et al., 2017; Roberts, 2018), could be used as a source of prevention against the skills mismatch, addressed to both doctoral students and industrial employers. Initiatives such as Marie Skłodowska-Curie actions already exist at the European level.

This research has some limitations. The considered universities are of different types: while KTH in Sweden is a technical university, UAB is a comprehensive university. The nature and amount of focus on technology transfer activities might thus differ. Furthermore, the parks are at different stages of maturity: the SSCP is fairly new, while PRUAB has a longer history. One area for further research is to compare each park with similar cases. Also, since the SSCP is newly created, strategies and interactions might be evolving very quickly; thus, it would be worth observing the SSCP's evolution over a longer period of time.

Notes

1. Overeducation refers to a situation in which an individual has more education than the current job requires (measured in years) (CEDEFOP, 2010).

2. Overskilling refers to a situation in which an individual is not able to fully utilise his or her skills and abilities in the current job (CEDEFOP, 2010).
3. See Isaksen and Karlsen (2010), who explain that the mode of innovation in regional industries significantly influences their level of cooperation with universities.
4. 'The Role of Universities in Innovation and Regional Development' is a research project funded by the European Commission.
5. An SME is a Small or Medium-Sized Enterprise.

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Appendices

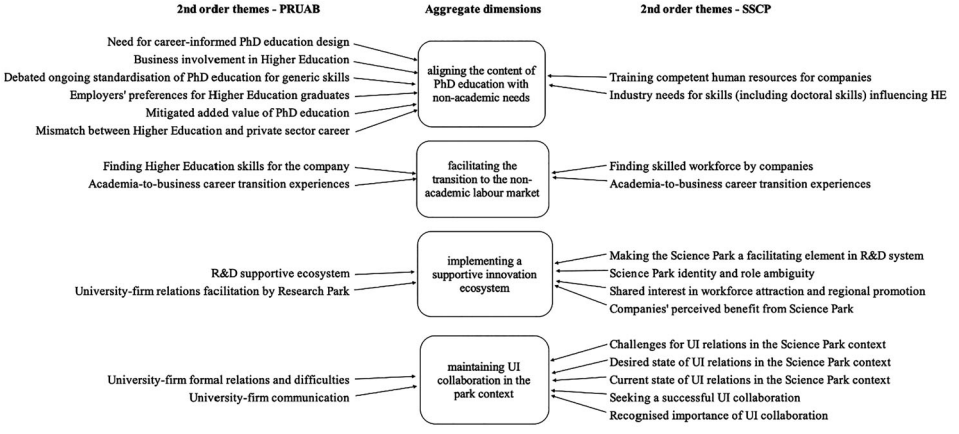
Appendix 1: Overview of the interviews

Case	SSCP	PRUAB
Number of interviews	8	9
Min-max length of interviews	27 min – 1 h 36 min	28 min – 1 h 11 min
Number of organizations represented		
• Of which, from the private sector	7	9
• Of which:	4	7
○ SMEs	2	6
○ Established companies	2	1

Appendix 2: Profiles of the interviewees

Case:	Interviewee code:	Type of organization:	Field of activity of organization:
SSCP	A	Engineering school	Higher education
SSCP	B	Engineering school	Higher education
SSCP	C	Science Park	Sustainable production
SSCP	D	Public organization	City management
SSCP	E	Multinational private company	Automotive industry
SSCP	F	Multinational private company	Pharmaceutical industry
SSCP	G	Research Park	Chemistry
SSCP	H	Small private company	Biomedicine
PRUAB	I	University	Higher education
PRUAB	J	Research Park	Innovation and entrepreneurship
PRUAB	K	Multinational private company	Material science
PRUAB	L	Private start-up, spin-off of UAB	Biomedicine
PRUAB	M	Private start-up	Environmental science and sustainability
PRUAB	N	Private start-up	Bioinformatics
PRUAB	O	Small private company	Biomedicine
PRUAB	*P*	Private start-up, spin-off of UAB	Environmental science and sustainability
PRUAB	Q	Private start-up, spin-off of UAB	Environmental science and sustainability

Appendix 3: Second-order themes and aggregate dimensions



Paper II

Article

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Collaboration of doctoral researchers with industry: A critical realist theorization

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Abstract

This article proposes a heuristic theoretical framework for identifying the main areas of policy improvement needed to enhance the engagement of doctoral researchers with industry. A critical realist approach is adopted in order to identify the factors underlying collaborations of doctoral researchers with industry. Following the initial three steps proposed by Danermark et al.'s *Explanatory Model of Social Sciences*, these factors are first identified at one level of abstraction and based on the findings of previous scholarly works on the external engagement of academics. They are comprised of academic disciplinary and contextual (regulatory and organizational) elements. After reviewing the prominent literature on each factor, a critical realist evaluation framework known as context–mechanism–outcome is implemented to integrate these underlying factors into an integrative and heuristic theoretical framework. Finally, the article discusses the research and policy implications of an interactive relationship between the disciplinary and contextual mechanisms that can shape different configurations for policy intervention to boost learning outcomes from collaboration.

Keywords

Collaboration with industry, critical realism, doctoral researchers, external engagement, transferable skills

The number of doctoral graduates in the developed economies has increased significantly since the turn of the 21st century (Auriol et al., 2013; OECD, 2014; UNESCO, 2017). In the context of these economies, one of the main purposes of this increase has been to ensure the flow of doctoral graduates to industry (Enders and Kaulisch, 2006; Pedersen, 2014). Nevertheless, the level of intensity of this flow has varied from country to country (cf. Lee et al., 2010; Pedersen, 2014). Furthermore, a clear distinction can be observed with regard to the employment sector composition of doctorate holders based on their academic field of study (cf. European Science Foundation, 2017). These findings imply that both national context and disciplinary differences have a significant influence on the career prospects of doctoral graduates in terms of their potential sector of employment.

In line with the increased flow of doctoral graduates to industry, studies have emphasized the need for doctoral researchers to be equipped with more generic and transferable skills in addition to specialized subject knowledge (Antony, 2002; Hancock and Walsh, 2016; Kehm, 2004; Sursock and Smidt 2010). Mobility placements of doctoral researchers during their education can help to develop the trust and new skills needed for further network-building outside their home university (Bienkowska and Klofsten, 2012). Interaction with firms provides them with significantly larger and stronger industrial social networks (Leonchuk and Gray, 2019), which in turn are likely to provide them with better labour market prospects (Thune, 2010). Nevertheless, the difference between academic disciplines with regard to the opportunities for such engagements with industry cannot be overlooked. While in applied fields of science the existence of communities of practice facilitates the intersectoral mobility of doctoral graduates, in other fields the differences in institutional norms and values inhibit such mobility (Millard, 2018). Therefore, improving the external engagement of doctoral researchers requires a nuanced understanding of the knowledge-field-specific characteristics affecting engagement opportunities. Furthermore, as mentioned above, findings of statistical differences across countries regarding the careers of

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doctoral graduates point to the importance of additionally considering national specifics.

In order to improve the opportunities for doctoral researchers' engagement with industry, and to enhance the outcomes of those engagements, it is necessary to elucidate what factors will determine a rise in such collaboration opportunities. The standpoint taken in this article is that, as a social phenomenon, the intersectoral collaborations of academics cannot be analysed by starting with data at the observable empirical level. The reason for this claim is that the heterogeneity of opportunity level (or extent) for engagement with industry among academics in general, and doctoral researchers in particular, is so high that, without acquiring a nuanced and in-depth understanding of the phenomenon, we risk conducting a skewed analysis that does not adequately represent the variations in opportunity levels.

The research paradigm of *critical realism* provides an appropriate ontological, epistemological and methodological framework for the above-mentioned concerns. As a research paradigm, critical realism is distinguished from the other paradigms specifically by its emphasis on ontological depth, or stratified ontology, maintaining that any social phenomenon can be studied at three ontological layers – namely the *real*, the *actual* and the *empirical* (Bhaskar, 1975). The layer (or domain) of 'real' constitutes structures or mechanisms that are not necessarily observable but exist independently of the researcher's knowledge about them and have *causal tendencies* that can lead to the emergence of 'actual' events. A researcher then observes only *some* of the actual events at the empirical level, but these observations are contextually conditioned (Bhaskar, 1975). The actualization of the causal tendencies from the real mechanisms is conditioned by the influence of contextual structures. In accordance with this framework, the collaborations of doctoral researchers with industry can be studied as a social phenomenon (an actual event), which materializes based on the disciplinary specifics of the knowledge field (which have a real epistemic structure). However, the influence of national and organizational specifics (contextual structures and mechanisms) conditions the actual occurrence of intersectoral collaborations (the actual events). The goal of empirical studies of these collaborations, then, would be to reveal the explanatory power of alternative theories on the causality power of those underlying mechanisms (Wynn and Williams, 2012).

Purpose of the research

This article proposes a heuristic theoretical model for analysing the factors that influence the external engagement of doctoral researchers in the form of collaboration with industry during their doctoral education. Comparing the expectations of employers in industry with the doctoral candidates' perspective, De Grande et al. (2014) find that doctoral candidates underestimate the importance of technical and transferable skills. This can create a mismatch of skills for doctoral graduates moving into the non-academic careers (Enders, 2004), and hence policies are expected to reinforce the mechanisms that facilitate intersectoral mobility programmes for doctoral researchers (Herrera and Nieto, 2016).

In order to improve science policy decisions, McNie et al. (2016) propose a multidimensional typology of research activities and their attributes, distinguishing between three main types of research activities: *knowledge production*, *learning and engagement* and *organizational and institutional processes*. In the context of current research, while the external engagement of doctoral students is seen as a learning and engagement activity, it is also seen as underpinned by the other two main dimensions of research activities; that is, knowledge production (driven by the academic disciplinary characteristics) and organizational and institutional (forming the contextual) processes. Mirroring this point in critical realist terms, the author is in agreement with de Souza (2013, p. 142), who suggests that '[. . .] in order to understand the effects of social programs and to explain change, there has to be a deeper understanding of pre-existing contexts and the mechanisms in operation prior to the introduction of any social program'.

Danermark et al.'s *Explanatory Model of Social Science* (2002) and Pawson and Tilley's *Realistic Evaluation* (1997) are among the most-referenced critical realist explanatory frameworks that deal with the issue of *causality* (Raduescu and Vessey, 2008). The aim of this article is to benefit from both these frameworks, albeit in different ways, in proposing a theoretical model for analysing the intersectoral collaborations of doctoral researchers as a social phenomenon underpinned by knowledge field disciplinary as well as contextual causes.

Danermark et al.'s *Explanatory Model of Social Science* proposes six steps for detecting structures and mechanisms in a critical realist research. These steps, which, according to Danermark et al., need not be followed in a strictly chronological order, include (1) description of events, (2) identification of key components or dimensions, (3) theoretical redescription (abduction) of components or dimensions, (4) retroduction – the identification of candidate mechanisms, (5) comparison of relative explanatory power of alternative theories and mechanisms and (6) concretization and contextualization of structures and mechanisms. According to Danermark et al., this model provides guidelines for relating the concrete to the abstract and vice versa in critical realist research practice.

Pawson and Tilley (1997) suggest 'context–mechanism–outcome' configurations (CMOcs) aimed at theory testing and refinement in relation to how social programmes activate mechanisms, among whom and in what conditions and leading to what outcome patterns. This approach is in line

with the implementation of retroductive research design in critical realist research, which is also at the heart of Danermark et al.'s model. The CMOcs are the explanatory components in the theorization and serve a proposition-building function (Pawson and Manzano-Santaella, 2012) regarding social regularities. The integrative section of the article will elaborate more on this framework, where a heuristic critical realist theoretical framework on the collaboration of doctoral candidates with industry is proposed by integrating the models from Danermark et al. and Pawson and Tilley. There, the goal is to investigate how the CMOcs framework pertaining to the collaborations of doctoral researchers with industry can be implemented following the first three steps in Danermark et al.'s model. The remaining three steps start with collecting the empirical data, as the fourth step (retroduction) implies.

In compliance with the first three steps in Danermark et al.'s model, the rest of this article is organized as follows. The next section is dedicated to describing the collaboration of doctoral researchers with industry, followed by a section which identifies the key dimensions of such collaborations with one level of abstraction. Then, the subsequent section seeks to redescribe the identified key dimensions based on concepts with explanatory potential, followed by the integrative section which proposes a theoretical model reassembling the key dimensions. The final section outlines how the proposed framework could provide a basis for empirical research that will verify the explanatory power of the proposed mechanisms underlying doctorate researchers' collaborations with industry. Consequently, the use of such research for deriving policies directed to the improvement of collaborative doctoral education is considered.

Description of doctoral researchers' collaboration with industry

The first step in Danermark et al.'s *Explanatory Model* comprises description of the event or phenomenon of interest. In this article, the phenomenon of interest is the engagement of doctoral researchers with industry during their doctoral education. Scholarly literature focusing on the distinctive features of collaborative doctoral education is rather scarce. Among the relevant studies, Granata and Dochy (2016), using activity theory, compare an academic PhD with a PhD performed in collaboration with industry. They refer to the latter as a 'semi-industrial' PhD and point out that this type of doctoral programme involves interaction with people from a non-academic background. The authors find that more common elements between the academic and semi-industrial PhD can be found in relation to the object (topic), the rules (guidelines) and the outcome (knowledge or product) of the studies. On the other hand, the differences between the two types are more pronounced in terms of the subject (skills acquired), the community (networks built), the division of labour (supervision roles) and the instruments of the activity system (facilities available to the researcher).

Borrell-Damian's (2009) report of the DOC-CAREERS project on collaborative doctoral education in Europe distinguishes two strategies and types of doctoral studies with the involvement of industry (as opposed to doctoral programmes with no involvement from industry):

- *Contract research*. In this arrangement, the university is strictly a supplier of knowledge and human resources for industry. It may include (1) outsourcing of the research by the company to the university or (2) a partnership whereby the university and company provide different specialist knowledge. Overall, the intensity of communication between the doctoral researcher and the company is low.
- *Collaboration*. In this arrangement, universities and industries are partners carrying out the research. It involves close communication and coordination between company, doctoral student and university. Different versions of this arrangement include (1) doctoral projects or programmes, (2) short-term internships, (3) short-term secondments, (4) joint research laboratories, (5) joint training programmes ('Chairs'). The main distinguishing feature from the low-intensity type, however, is considered to be the joint supervision.

Consequently, Borrell-Damian (2009) identifies a set of main components characterizing these varieties of collaborative doctoral programmes. These components include (a) the strategic level of engagement in the organization (university and industry), (b) the role of the industrial partner, (c) the selection of the doctoral research topic, (d) the additional admission requirements for doctoral candidates, (e) the formal agreement and general conditions, (f) the legal status of the doctoral candidate and (g) the supervisory scheme. In a follow-up study, named DOC-CAREERS II, Borrell-Damian et al. (2015) found the following areas as those typically covered when establishing a formal agreement between the partners in a collaborative doctoral scheme: general rules for collaboration including the duration of joint research, committed resources, confidentiality issues and intellectual property ownership, description of the research project and the rights and duties of each party.

In a rather similar approach to Borrell-Damian's (2009) distinction between contract research and collaboration, Kitagawa (2014) distinguishes between *centre format* and *non-centre format* collaborative doctoral programmes in Europe and beyond. These formats refer to two distinct institutional forms of organizing such collaborative doctoral programmes. They are both differentiated from traditional PhD programmes as doctoral researchers are

expected, under these collaborative programmes, to work directly with industry. In Europe, in the non-centre format, as Kitagawa (2014: 336) explains, 'the collaborative programmes support individual doctoral students within the existing academic units, rather taking the forms of autonomous research centres', which is the case of centre format. Elaborating further on the case of United Kingdom, Kitagawa finds that centre format programmes tend to be more applied than non-centre format programmes. A more important difference, however, is considered to be the forms of employer engagement. In the centre format, the employer's involvement in project design, supervision and skills development is more substantial, and the length of this involvement is significantly longer than in the case of the non-centre format.

Identification of key dimensions of external engagement

The second step in Danermark et al.'s *Explanatory Model* relates to the identification of key components or dimensions in the described social phenomenon. It is at this step that abstraction starts and, accordingly, we shall also look for the key dimensions of doctoral researchers' collaboration with industry at a more abstract level; that is, the external engagements of academic researchers in general.

Reviewing the literature on university–industry relations, Perkmann et al. (2013) identify three categories of antecedents of external engagement by academic researchers: *individual*, *organizational* and *institutional*. The institutional factor consists of both regulatory (public policy) and disciplinary components. Organizational factors relate chiefly to university-level and department-level characteristics. Based on the discussions provided, the present article aims to identify policy intervention areas for higher education, focusing on doctoral students' external engagement, through the cross-fertilization of disciplinary, regulatory and organizational factors influencing such engagement. The 'individual' category is exempted from the scope of this article: Herrera and Nieto (2016) also confirm that, overall, studies have not obtained significant and conclusive results from the analysis of variables such as gender, age and marital status.

As Becher and Trowler (2001) put it, the organizational, cognitive and social frameworks surrounding an academic's working life interact and at some points interpenetrate. When it comes to doctoral education, the interaction of these three frameworks, which are strikingly similar to the categories of antecedents identified by Perkmann et al. (2013), can considerably influence the external engagement possibilities and, hence, the learning opportunities of doctoral researchers. Nevertheless, the extant literature suffers from the lack of an overarching framework that is able to explain the relations linking these engagement antecedents to each other. Consequently, it is not clear how higher education policies can identify specific leverage points based on the specific set of combinations of antecedents that can be observed in different higher education systems or in university–industry collaborations. Therefore, this article seeks to develop a theoretical framework that will bring together coherently the antecedents of external engagement and enable conceptualization of the resultant modes of policy improvement.

Based on the above discussion, the next section elaborates on the disciplinary, regulatory (policy-related) and organizational antecedents of doctoral researchers' external engagement (collaboration) with industry. A synthesis (integration) section will then demonstrate how the overarching framework can be used for hypothesizing and comprehending the interactions of the antecedents of engagement with industry, connecting them with the engagement outcomes in terms of skills acquisition.

Theoretical redescription of the key dimensions (abduction)

The third step in Danermark et al.'s (2002) model concerns a redescription of the identified key dimensions of the phenomenon of interest. In this part of the article, therefore, the identified three key dimensions of external engagement of academics will be redescribed based on a set of theoretically informed literature elucidating those dimensions.

Disciplinary antecedent

Scholarly works have demonstrated that academic disciplines vary significantly with regard to the perceived importance of external funding and collaboration (Bozeman and Gaughan, 2007; D'Este and Iammarino, 2010; Klofsten and Jones-Evans, 2000). Bienkowska and Klofsten's (2012) study of PhD students at Linköping University in Sweden showed that, while mobility placements in the private sector were more prevalent in the Faculty of Science and Engineering, mobility placements at other universities and public organizations were higher in the Faculties of Arts and Humanities (including social and educational sciences) and Health Sciences. Rahmandad's (2013) findings on the role of PhD students and postdocs in the faculty's research distinguished between the solo and funded research models, the former comprising social sciences and mathematics and physics and the latter engineering and applied fields of science. All these research findings point to the importance of adopting a nuanced approach by acknowledging the interdepartmental differences when analysing the potential for and the actual engagement activities in the form of mobility and collaboration during PhD education.

In the higher education research literature, the *academic tribes and territories* (henceforth ATT) thesis has been highly influential during the last three decades due to its

Table 1. Broad disciplinary groupings.

Biglan	Kolb	Disciplinary areas
Hard pure	Abstract reflective	Natural sciences
Soft pure	Concrete reflective	Humanities and social sciences
Hard applied	Abstract active	Science-based professions
Soft applied	Concrete active	Social professions

Source: Becher (1994).

debated capability to explain the relationship between knowledge domains and the practices of academics. As explained by Trowler (2014a), the ATT thesis argues that the knowledge structure (or epistemological core) of disciplines has social and cognitive dimensions. The social dimension was originally developed by Becher (1984, 1987) and concerns whether or not, and to what extent, disciplines have uniform research standards and involve the intense interaction among researchers. The cognitive dimension is influenced by the seminal works of Biglan (1973) and Kolb (1981) on the differences between academic programmes and environments using the concept of disciplinary cultures. The social and cognitive dimensions are interrelated. Becher (1994) refers to the similarity of disciplinary categories resulting from Biglan's 1973) and Kolb's (1981) work, the former being concerned with the subject matter of research and the latter with the style of intellectual inquiry (see Table 1). Neumann et al. (2002) refer to the resulting categorization of disciplines as Becher–Biglan typology, which categorizes the disciplines into hard pure, soft pure, hard applied and soft applied fields.

The first version of the thesis was formulated by Becher (1989), based on interviews with academics and researchers in the United Kingdom and United States. In a nutshell, according to the thesis,

> [. . .] the knowledge structures of disciplines (the academic territories) strongly condition or even determine the behavior and values of academics. In this account, academics live in disciplinary tribes with common sets of practices, at least as far as research practices are concerned [. . .] (Trowler, 2014a, p. 18)

As Nerland et al. (2010) put it, the research on disciplinary cultures helps towards an understanding of how different knowledge domains generate distinct patterns of social organization. This is due not least to the methodological differences among them. Alise (2008) points to this aspect of differences between pure and applied knowledge domains, including sampling methods and data collection methods. Pinheiro et al. (2012) find that applied fields are more likely to engage with external parties than are pure fields and specifically that the hard pure fields benefit least internally from external engagement and deliver the lowest external impact on society.

Nevertheless, the authors and proponents of this structuralist view of academic disciplines did not leave it unchanged over time. The second edition of the book on the thesis, co-authored by Becher and Trowler (2001), placed greater emphasis on contextual factors as it strove to account for some of the significant epistemological and contextual changes to higher education that had occurred during the late 1980s and 1990s. These included, among others, the impact of mode 2 knowledge production as well as triple helix linkages between universities, the state and industry. Nevertheless, as the authors explain in the preface to the second edition:

> The book remains an enquiry into the nature of the linkages between academic cultures (the 'tribes') and disciplinary knowledge (their 'territories') and so excludes detailed discussion of other influential factors in conditioning faculty cultures in higher education. (Becher and Trowler, 2001: xiv)

Later, a third book followed the discussion about the thesis, this time co-edited by Trowler et al. (2012). In this text, the epistemological essentialist view is replaced with a social practice approach. Therefore, the book distances itself further from the essentialist view, which was based on the significance of the epistemological core of academic disciplines. Accordingly, academic disciplines are considered in this 2012 book as open systems conditioned by social and material characteristics as well as agent-specific influences. Trowler (2014b) therefore proposes shifting towards a postmodern perspective of disciplines, as the 'territories' need to incorporate factors that condition them over time and across place or other contextual contingencies. Accordingly, he argues for 'moderate essentialism', explaining that

> Technologies, ideologies, marketization, globalization and the rise of the evaluative state among other forces at play condition, in their interactions, how academics behave. (Trowler, 2014b: 1723)

The next section deals with one of the key elements that contextualize the disciplinary influence on external engagement, the national policy and regulatory frameworks for higher education in general and doctoral education in particular.

Regulatory and national policy antecedents

Regulations and public policy constitute an institutional factor found by Perkmann et al. (2013) to be an important antecedent of academics' external engagement. The impact of such policies can be witnessed at various levels of policymaking (e.g. national, regional or organizational level)

depending on the public policy narrative dominating the national higher education system. Government policy can have a very powerful effect on the core processes of academic work, and the impacts across disciplines and institutional contexts are different (Neumann, 2007). In other words, the extent to which public policy influences academic work is not identical across knowledge fields, and the way in which the combination of disciplinary and policy elements exert their influence varies across the different institutional contexts of different countries. Gläser and Laudel (2016) discuss the relationship between science policy and research content and mention that the allocation of resources and funding has been, and is likely to remain, a stronger channel of policy influence on research content than channels such as hierarchical steering. Accordingly, there is a difference in how much different countries' policymakers can influence, for example, the number of PhD graduates based on the extent to which the PhD education is publicly financed (Pedersen, 2014). In the Nordic countries, where PhD education is publicly financed, the influence of national science and higher education policies on the number of doctoral researchers is more direct.

The mode of engagement of public policy entities in the higher education sector, however, depends on the public management narrative that underlies the logic of intervention by those entities. Baschung (2010) uses a theoretical framework consisting of three public management narratives in the public sector – new public management (NPM), network governance (NG), and neo-Weberian-state (NWS) – in order to analyse changes in the management of doctoral education. Based on these three narratives, Baschung identifies the management story behind effective reforms of doctoral education. In a nutshell, while the NPM narrative emphasizes efficiency, performance measurement and marketization, the NG and NWS narratives concentrate, respectively, on shared, multi-actor coordination, and legitimate, state-led but user-centric public management (cf. Ferlie et al., 2008). While the United Kingdom is considered a key index case for NPM, Germany is mentioned as a case in which the signs of NG are more evident, and France exemplifies NWS reform based on the growth of regional government of higher education since the 1980s. With regard to the governance of higher education institutions and the implications for managerial roles, Ferlie et al. (2008) consider the following signs as indicators of the application of NPM ideas to the higher education sector:

- in the realm of governance, the development of 'strong rectorates' and non-executive members drawn from business;
- a move to appointed rather than elected senior posts;
- a reduction in the representation of faculty and trade unions in higher education institution governance;
- stronger overt managerial roles for rectors, deans and head of departments; and
- the development of 'management must manage' doctrines and practices – that is, those who have responsibility for management must have the means and the will to manage ('liberation management' NPM subtype).

Broucker et al. (2015) identify the four key characteristics of NPM as marketization, budgetary reforms, autonomy complemented by accountability and a new management style (more hierarchical). Considering the NPM-related reforms in 10 countries, the authors conclude that the timing, intensity and content of the reforms are not identical across different countries. Nevertheless, it can be observed that, since the NPM narrative exposes the higher education (HE) system more openly to market forces, the implication for research collaborations is that the 'applied' group of disciplines is likely to be favoured.

Ferlie et al., (2008) also provide, among others, the following as symptoms of the application of the NG narrative in the higher education sector:

- a shift in the role of the state from directing to a more indirect role;
- the development of networks between higher education institutions and between higher education institutions and other social actors;
- the design of some networks with the explicit goals of joint problem recognition, joint problem solving, organizational learning and the dissemination of 'good practice' and leading-edge knowledge; and
- in terms of senior management style, an emphasis on softer leadership skills, visioning and networking-based approaches and on distributed leadership and team-based approaches as opposed to the highly individualized management typical of NPM.

Given the decentralized and network-based nature of the NG narrative, compatibility can be recognized with the mode 2 knowledge production framework (Gibbons et al., 1994) and the triple helix of university–industry–government relationships (Etzkowitz and Leydesdorff, 1995). Hence, application of this narrative in higher education policymaking might be more conducive to *transdisciplinarity*, an approach which also aims at engaging various stakeholders in real-world problem solving. Accordingly, the moderate (or weak) essentialist approach suggested by the third book on the ATT thesis – Trowler et al. (2012) – is better able to comply with the attributes of this narrative because disciplines are considered as open systems influenced by multiple agents.

With regard to indications of the application of the NWS narrative in the higher education sector, Ferlie et al., (2008) include, among others, the following symptoms:

- the state continues to steer the higher education sector strongly as it is of strategic significance to society as a whole;
- the creation and use of focus groups, stakeholder fora and more elaborate consultation processes that feed into strategy making; and
- the use of elections for senior management positions, such as rectors and heads of department.

Due to the stronger role of the state in the NWS narrative, the group of disciplines that are considered 'pure' (as opposed to applied), and hence not directly driven by business sector demands, might better benefit from this governance narrative in terms of access to resources for external engagement.

Another key aspect of doctoral education that can be significantly be influenced by regulations at the national level is the types of doctoral education that are recognized. Bao et al. (2018) analyse recent changes in doctoral education in Europe and China. They show that in Europe doctoral education has become an object of not only institutional management and national policymaking but also of supranational agenda setting. Based on Kehm's (2009) work, the authors identify nine different types of doctoral education and training in Europe, which include the following:

- *The research doctorate*. In this model, the dissertation is central and is acquired within the framework of a structured or master–apprentice relationship. The dissertation is expected to be an original contribution to the knowledge base of the research domain.
- *The professional doctorate*. This model is not awarded in all disciplines but is limited to subjects with a relatively demarcated field of professional practice – for example, medicine and healthcare, social work and engineering. The dissertation is expected to contribute to the respective professional practice. The United Kingdom, France, the Netherlands, Belgium, Austria and Denmark are among the countries to have adopted this model.
- *The taught doctorate*. This model consists of a substantial proportion of course work, and the courses are spread over the whole period of degree training. This model is predominantly offered in the United Kingdom.
- *PhD by published work*. This model is characterized by combining several articles that have appeared in peer-reviewed scholarly or scientific journals into a book. A programme of additional studies of regulated form is usually included. This model originated in Germany but has now spread to other European countries including Belgium, the Netherlands, Sweden and Norway.
- *The practice-based doctorate*. This type denotes the award of doctoral degrees in the arts and design and is awarded in the United Kingdom and Australian university systems. This model is also predominantly implemented in the United Kingdom.
- *The 'new-route' doctorate*. This model, also known as the 'integrated doctorate', consists of three elements: a taught component in the area of research methods and subject specialization, another taught component in the area of transferable skills and the work on the dissertation. Admission can be granted immediately after completion of a bachelor's degree. This model was developed in the United Kingdom, and in Germany it is known as the 'fast track PhD'.
- *Two models of the joint doctorate*. In the joint doctorate model, doctoral programmes are jointly offered by two or more universities. Germany, Spain, France, Italy, the Netherlands and the United Kingdom are the main countries offering this type of PhD education. A particular variant of the model is the 'European doctorate', which has not yet been implemented in practice.
- *The cooperative doctorate*. In this type, professors from universities and universities of applied sciences jointly supervise a doctoral candidate. It is specifically offered at German universities.
- *The industrial doctorate*. This model is used mainly in engineering fields and is a rather applied degree. Research work is carried out with the goal of solving a particular problem in a company. This type of doctorate is most frequently to be found in the Scandinavian countries and France.

Bao et al. (2018) explain that this proliferation of types and models of doctoral education reflects the variety of motives and interests of the expanding number of doctoral candidates, specifically due to non-academic career prospects (see also Padro et al., 2018). This consideration, according to the authors, has led to a 'need to acquire a considerably broader set of skills and competences' (Bao et al., 2018: 540). The influence of disciplinary specificities on the formation and conduct of some of the abovementioned types of doctoral education is obvious and in some cases makes the external engagement of the doctoral student an integral part of the education. The spreading of some of these models from a country of origin (mostly the United Kingdom or Germany) to other countries suggests that the governance framework of the higher education system, which in some cases varies significantly (e.g. with regard to the financing of PhD education), does not always overcome the institutional influence emanating from epistemological essentialism.

Organizational antecedents

The organizational dimension influencing the collaborations of doctoral researchers with industry can be studied

with regard to several features. First, the expected role of the doctoral researcher can have an influence on the organizing of the interaction. Thune (2009) considers three roles for doctoral researchers at the university–industry interface, as producers of knowledge in an altered environment, as part of the wider distribution of knowledge and as nodes in university–firm networks. Bienkowska et al. (2015) discuss the idea of triple helix permeability, which refers to 'the ability to move people and exchange ideas within and among institutional spheres' (Bienkowska et al., 2015: 262). Within this framework, the authors discuss PhD students' networking, mobility and entrepreneurship intentions. They point to the need for an 'organized framework' to promote mobility and networking among PhD students, specifically in cases that having intersectoral interactions is not a norm in a university.

Another factor influencing the organization of interaction with industry is the institutional structure of doctoral education in the university. Institutional structures for doctoral education in European universities are diverse, but increasingly, over the past decade, doctoral programmes and schools have become the prevalent ones (EUA-CDE, 2019; Kehm et al., 2018). These are organized mostly at the disciplinary or faculty level (EUA-CDE, 2019).

Another important feature is the way the intersectoral collaboration itself is organized. In a systematic review, and following Bonarccorsi and Piccaluga's (1994) earlier work, Ankrah and Al-Tabbaa (2015) categorize the organizational forms of university–industry collaboration into six groups, namely personal informal relationships, personal formal relationships, third party, formal targeted agreements, formal non-targeted agreements and focused structures. The level of organizational involvement increases each time moving from the first to the last category – so much so that in the focused structures the entire university is involved in collaborating with industry (e.g. through establishing innovation centres, science and technology parks, etc.). Each of these organizational forms for university–industry collaboration obviously provides a different level of opportunity for the external engagement of doctoral students with industry. However, Ankrah and Al-Tabbaa (2015) point to the shortage of studies that have investigated the consequences of engagement with industry for the learning experience of students. There are a few exceptions, however. One is Wallgren and Dahlgren's (2007) study concerning the influence of organizational practices and routines in various collaborative arrangements on the learning experience of industrial doctoral students. They show that there is a large variation in the learning trajectories of the doctoral students and identify five factors that create that variation. These include entrance conditions, the doctoral thesis project, the organization of the research school, supervision and students' aspirations. According to the authors, when it comes to the organization of the school, the form, the importance and the participation level of doctoral students vary among thematically different industrial research schools. Another relevant study is that by Assbring and Nuur (2017), who find that the industrial outcomes (relevance) of doctoral researchers' industrial participation are highly connected to the organization of the collaboration. By studying three industrial PhD schools in Sweden, the authors identify four criteria as key to ensuring the industrial relevance of the organization of university–industry collaboration: co-financing, joint supervision, joint formulation of the research project and structured placement (time spent) of the doctoral candidate at the firm.

A final organizational factor relates to the overall features of the university and the way these might influence the external engagement of academics. Thune et al. (2016) study the influence of university-level characteristics on the external engagement of academics, concluding that these characteristics, when controlled for the influence of individual and discipline-level factors, do not explain much about the differences in external engagement among academic staff. According to the authors, only consultancy and commercialization activities are influenced by university-level factors, while dissemination, external training and research collaboration are types of external engagement that are not influenced by institutional-level factors.

Integrative theoretical framework: CMOcs

At the end of the third step in Danermark et al.'s six-step model, and before proceeding to the fourth step, during which the empirical research methodologies are employed in order to conduct a retroductive inquiry, the abducted dimensions in the third step need to be integrated. Therefore, the aim at this stage is to propose a heuristic theoretical framework which interrelates and integrates the key dimensions that we have, in an abductive way, described as being prominent in influencing the collaborations of doctoral researchers with industry. These include the 'real' mechanism (i.e. the disciplinary factor that refers to the causal tendency of epistemic structure of the academic knowledge field) as well as the 'contextual' mechanisms (the policy/ regulatory and organizational factors). Pinheiro et al. (2012) conclude, from their study of the patterns of external engagement of academics, that the categorization of disciplinary knowledge structures has both advantages and shortcomings. An advantage, according to the authors, is that it helps in extracting the general patterns of behaviour specific to knowledge domains. The shortcomings, on the other hand, relate to an overemphasis on the epistemological dimension of disciplines to the disadvantage of the contextual factors in which specific academic communities operate. Therefore, in order to hypothesize about the causal structures underlying the external engagements of

doctoral students, it is necessary to consider the epistemic and contextual factors in an integrated framework.

As mentioned earlier, when setting out the purpose of this article, Pawson and Tilley's CMOcs framework, as a prominent explanatory model within the research paradigm of critical realism, provides a basis for a context-informed analysis of the causality of real mechanisms. In other words, the key components of the phenomenon of intersectoral collaborations can, in complying with the CMOcs framework, be differentiated to real mechanism and contextual components, which together result in the formation of programmes and the emergence of outcomes – that is, the realization of collaboration and its consequences for doctoral researchers in terms of skills acquisition. While the policy/regulatory and organizational antecedents to the external engagement represent contextual factors, the disciplinary antecedent, in line with the ATT thesis, represents the real mechanism underlying the occurrence of collaborations due to the causal tendencies of the epistemic structure of knowledge fields on the collaborations of academics. This attribution of the real mechanism to the implications of the ATT thesis is in line with Pawson (2006), who states that social programmes are 'theories incarnate'. This point can be interpreted here by viewing doctoral programmes that include collaboration with industry as manifestations of the epistemic structure of those academic disciplines that have causal tendencies towards applied research in industry. Furthermore, Pawson and Tilley (1997: 68) understand mechanisms as 'a theory which spells out the potential of human resources and reasoning'. Hence, according to them, the mechanism of social programmes aiming at change consists of resources and reasoning. Then, as Dalkin et al. (2015: 4) also elaborate, in a critical realist understanding of a social programme, '[i]ntervention resources are introduced in a context, in a way that enhances a change in reasoning. This alters the behaviour of participants, which leads to outcomes'. Accordingly, in our case, the cognitive dimension of disciplines (see section 'Disciplinary antecedent') is here seen as forming the initial 'reasoning' mode of participants in the collaboration, meaning that transferable skills can be acquired through their participation in collaborative doctoral programmes that expose the doctoral students to a new type of cognitive capability. The resources, which might be introduced differently in different contexts (e.g. through various ways of funding of doctoral programmes), are the part of mechanisms that interact with the disciplinary-driven mechanisms in order to achieve enhanced reasoning (i.e. the new skills).

As outlined in the section 'Disciplinary antecedent', the later versions of the ATT thesis have moved towards attributing to the epistemic core of disciplines a weak essentialism, giving way to the moderating effect emanating from the *social practice* of disciplines. At its extremes, therefore, the ATT thesis provides two alternative (or, eventually, complementary) theories feeding the 'real mechanism' component of our CMOcs model. The two extremes are disciplinary essentialism versus the social practice of disciplines. Their respective explanatory power, and hence that of the programme theory, can be determined after the implementation of retroductive empirical research – that is, steps 4 to 6 in Danermark et al.'s model.

In the case of the external engagement of doctoral researchers, different configurations can be identified leading to varying degrees of influence being exerted by the epistemological essentialism (the disciplinary knowledge structure). This means that contextual factors, including national higher education and doctoral education policies and regulations, as well as university-level and department-level characteristics, will interact with the real mechanism and lead to different outcomes (i.e. different levels or types of transferable skills acquisition). Figure 1 demonstrates the proposed heuristic CMO model underlying the emergence of configurations for doctoral students' collaboration with industry based on the types of confluence of the antecedents discussed. The resulting CMOcs can be then compared with the initial hypothesized theory about the causal power of the real mechanism, which is modified (or not) in the light of the evaluation findings.

As Figure 1 shows, in complying with the stratified ontology in critical realism, the social reality is represented at three levels:

- *Domain of the real.* At this layer, the mechanisms emanating from the real but unobservable structures, including those of epistemic core of disciplines and also institutional (regulatory) and organizational 'powers', exert their influence on the formation (occurrence) of the event – the collaboration of doctoral researchers with industry. The term 'higher education system' refers to all institutional entities which, in a given context (e.g. a country), have influence on the HE sector – so it can include private and public institutions (hence the term *system*), the former being specifically pronounced in NPM and NG narratives. Then, according to the version of ATT thesis driven by social practice, the contextual factors might influence the epistemic core of (some) disciplines, and, if this is going to materialize, the academic departments are the entities that will finally channel the influence.
- *Domain of the actual.* At this layer, the interactions of mechanisms derived from the domain of the real lead to the emerging of actual social 'events'. In other words, whether or not the epistemic structure of disciplines can fully affect the formation of doctoral programmes with a certain expected regularity pattern in terms of intersectoral collaborations will depend on the confluence of tendencies from the contextual structures (regulations and policies). These mechanisms, through the specifics of the

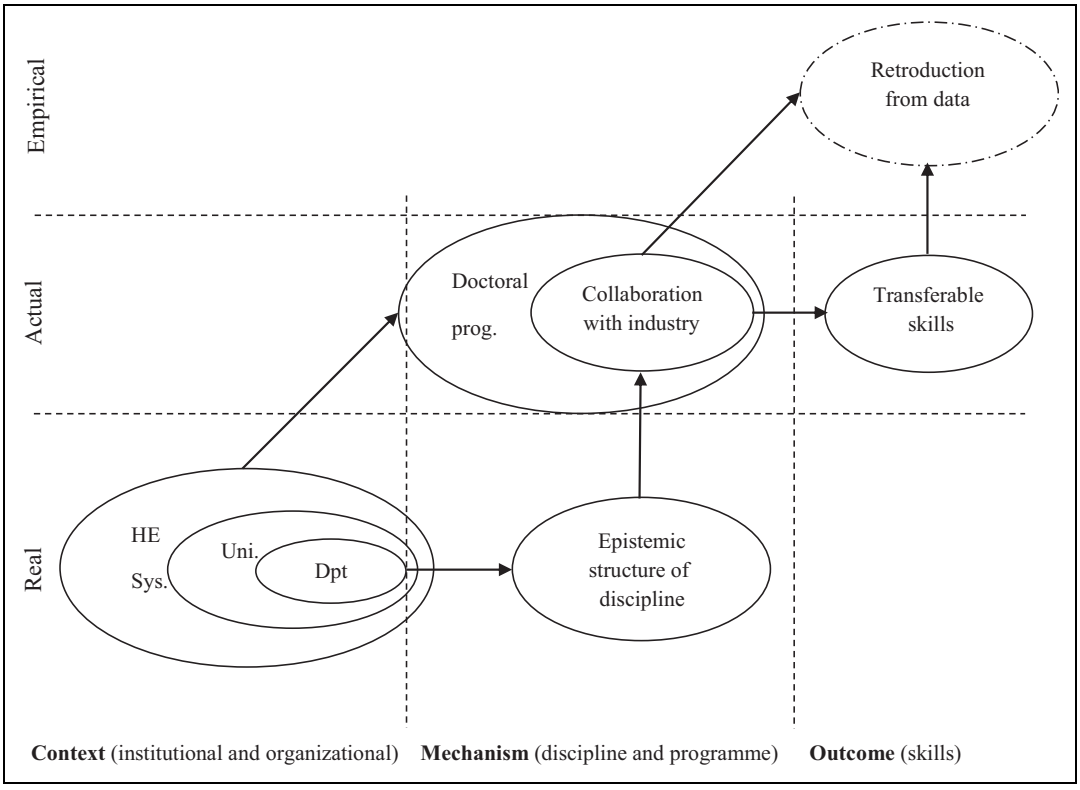

Figure 1. Context–mechanism–outcome model for the collaboration of doctoral students with industry.
Source: Author's own origination.

doctoral programme, can to different degrees provide potential for achieving the targeted outcome – that is, the acquisition of transferable skills, based on the programme's specific forms and intensities for intersectoral collaboration.

- *Domain of the empirical.* At this layer, observations are made on some of the actual events and their outcomes. The empirical data generated kick off the retroduction, which aims to refine the theories underpinning the regularities stemming from the CMOcs. Quantitative and qualitative research methods can be implemented to study the intersectoral collaborations of doctoral researchers and their outcomes in terms of skills acquisition. Retroduction 'is a method for finding the prerequisites or the basic conditions for the existence of the phenomenon studied' (Danermark et al., 2002: 1). To achieve that, a retroductive inference advances from empirical observations to a conceptualization of transfactual (i.e. beyond the empirical) necessary conditions.

Based on the appraisal made through retroduction of the explanatory power of mechanisms and structures, which constitutes the fifth step in Danermark et al.'s *Explanatory Model*, revised CMO configurations will be proposed. These CMOcs are proposed referring to concrete situations, based on observations made of the interaction of mechanisms in a specific context studied. This concretization and contextualization constitutes the sixth (and last) step in Danermark et al.'s *Explanatory Model*. Policy intervention areas for boosting the skills learning experience in collaboration during doctoral education can be derived from a resultant revised theoretical framework about the causality of mechanisms. The next section briefly elaborates the implications of the proposed heuristic model for further research and policy.

Implications for higher education policy and further research

The aim of the heuristic theoretical framework developed in this article is to develop a context-aware understanding of the causal power of academic disciplines as the real mechanisms underlying the external engagements of doctoral researchers with industry. At its core, the model hypothesizes that while the disciplinary characteristics are, according to the implications of the ATT thesis, the main cause of differences in the collaboration patterns of doctoral researchers with industry, the higher educational regulatory and organizational contexts modify the form of and the extent to which the causality of that main mechanism actualizes. The confluence of these disciplinary and contextual mechanisms leads to different forms

of organizational arrangements for the interaction of doctoral researchers with industry. Accordingly, and based on the specifics of context–mechanism interactions, the outcomes for the doctoral researchers in terms of skills acquisition differ, as the various organizational arrangements of collaboration differ in terms of providing opportunity for the acquisition of various transferable skills.

The purpose of retroduction in critical realist research is to ascertain the explanatory power of theories associated with the mechanisms causing the events. Accordingly, the implication of the proposed framework – for which retroduction would be the next step – regarding the empirical research is to examine:

a) whether the empirical data confirm the attribution of more causal power to the strong essentialist or social practice interpretation of the ATT thesis concerning the influence of the epistemic structure of academic disciplines on the collaboration of doctoral researchers with industry; and
b) how the contextual factors (including national and organizational antecedents) interact with the causality of the disciplinary mechanism in the formation of opportunities for intersectoral collaborations of doctoral researchers and, consequently, their transferable skills acquisition.

Based on the results from the prospective empirical research, the implications for policies to boost the prevalence of collaborative doctoral programmes and their outcomes can therefore be derived. First, the emerging CMO configurations will lead to a revision or confirmation of the theories concerning the extent of the dependence of collaborations on the epistemic character of the knowledge field vis-à-vis contextual mechanisms.

Furthermore, the type of higher education public policy narrative in a country affects the nature of its influence on policies at the organizational level (i.e. at university and department levels) – see 'Regulatory and national policy antecedents' section. University-level policies function as another contextual mechanism affecting, and possibly modifying, the impact of the disciplinary mechanism. Returning to McNie et al. (see 'Purpose of the research' section), it can be argued that policies concerning learning and engagement activities first need to comprehend the interaction of the knowledge production mode with organizational and institutional processes. Asheim (2011) points out that mode 2 universities not only adapt to but also 'organize' the research for innovation processes in firms. This, in turn, can give rise to new designs of doctoral research schools or programmes in which inter-organizational as well as inter-departmental collaborations are based on more participatory (internal and external) governance modes.

Another implication of the proposed framework is that institution-level policies concerning collaborative doctoral programmes need not be homogeneous within the same university. In fact, an academic department bears both the contextual and knowledge field traits underlying the actual organization of a doctoral education programme. With regard to the organizational level of engagement with industry (see 'Organizational antecedents' section), it can be argued that, based on the aforementioned influence of disciplinary differences, departmental characteristics can vary within the same university due to varying degrees of compatibility and correspondence between the contextual and disciplinary traits. These inter-departmental differences, depending on the university-level policy framework or higher education sectoral specifics, may lead to the adoption of different forms of doctoral education (professional doctorate, industrial doctorate, collaborative doctorate, etc.) by different departments. This, in turn, would imply a need for different forms of institutional policy intervention in order to boost systemically the opportunities for external engagement of doctoral students with non-academic sectors.

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Paper III

Intersectoral Engagements of Doctoral Candidates: Regime Discrepancy Between Academic Territories

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Abstract

The paper aims to analyze whether and to what extent collaborations of doctoral researchers with the non-academic sectors is determined by their disciplinary affiliation. For this purpose, the paper uses data collected from a survey of doctoral researchers at four universities from three Scandinavian countries. Relying on a critical realist research paradigm, the paper assesses the explanatory power of Academic Tribes and Territories (ATT) thesis in terms of the relation between disciplinary groups and prevalence of intersectoral research collaborations for doctoral candidates. ATT thesis puts forward, throughout its development over time, two opposing perspectives around the degree of essentiality of disciplines in determining the professional behaviour of academic researchers. The collected survey data is analyzed in the paper using a logit regression model. The results from the analysis show that different regimes can be applied to explain the essentiality of different "academic territories" in terms of influencing the intersectoral collaborations of doctoral candidates. On the one hand, for the hard-pure and soft-applied categories of disciplines in Becher-Biglan's typology, the epistemological essentialism proves strongly capable of explaining the prevalence of intersectoral collaborations of doctoral students. On the other hand, in case of the hard-applied and soft-pure disciplines, the contextual factor represented by the country and university variables proves significant, leading to the predominance of social-practice-based understanding of intersectoral research collaboration within those fields.

Keywords: *doctoral education, intersectoral collaboration, collaborative doctorate, Academic Tribes and Territories, epistemological essentialism, social practice*

Introduction

Recent decades have seen a steep increase in the number of doctoral degrees awarded every year across most European countries (cf. OECD, 2014). This trend has led to a shrinkage in the share of doctoral graduates getting employment opportunity at the academic sector (Nerad *et al*., 2008; McAlpine & Emmioglu, 2014; Roach & Sauermann, 2017). This is partly due to the

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fact that the number of academic vacancies have not been increasing at a similar rate to the number of doctoral graduations, which implies that preparing for a career outside academe is now a necessary consideration during doctoral education. Doctoral candidates' perceived preparedness for such career paths, however, is significantly different among academic disciplines (Heflinger & Doykos, 2016).

Engaging in research collaborations with non-academic sectors during doctoral education is one of the most effective ways for doctoral researchers to prepare for transition to a non-academic career after graduation (Thune, 2010). Accordingly, improving the opportunities for such collaborations during doctoral studies becomes a higher education policy target (Nerad *et al*., 2008; Bernstein *et al*., 2014). The occurrence of such collaborations, nonetheless, is dependent on various factors, some of which are context-laden and others more inherent in the capacities existent in the academic field. Chikoore *et al*. (2016) found that there exists an association between academics' disciplinary groups and their preferred audience for public engagement. Also when it comes to engagement with industry, previous research has indicated that disciplinary affiliation plays an important role (Franco and Haase, 2015; Ponomariov, 2008; D'Este and Patel, 2007). Hence, a question can be raised whether the same type of policy can be applied across all the academic fields to achieve an increased level of intersectoral collaboration during doctoral education. In other words, it can be questioned whether the academic discipline is such a significant factor in determining the intersectoral collaboration opportunities for doctoral researchers that would necessitate distinct policies for distinct disciplinary areas. This paper aims at finding an answer to such a question through an empirical, quantitative research based on a survey of doctoral candidates in four universities from three Scandinavian countries.

Building on the Academic Tribes and Territories (ATT) thesis, which over a couple of decades since its inception has witnessed the rise of somewhat opposing theoretical positions within it, this paper seeks to assess the explanatory power of disciplinary groups about the prevalence of intersectoral collaborations among doctoral researchers. While the initial texts on the ATT thesis attributed the disciplinary factor with a high significance in determining the professional behaviour of academics (Becher, 1989), the latest textbook following up the discussions around the same thesis has acknowledged a more important role for the social context in shaping the academics' professional practices (Trowler *et al*., 2012). The appreciation of causal power for the epistemic core of disciplines, then, makes critical realism stand out as the research paradigmatic lens corresponding to the undertaken worldview. This is because critical realism

acknowledges that some causal mechanisms emanate from unobservable real structures which are not directly experienced, but have *generative power*, and hence theories around their causal power need to be *retroduced* based on observations. The application of critical realism in the investigation of external engagement of doctoral researchers is theoretically elaborated by Moghadam-Saman (2019). The appraisal of ATT's alternative theories in terms of their capability in explaining the causality around the research behaviour of academics, conforms with the 'retroduction' step in critical realism (cf. Danermark *et al*., 2002). Within critical realism, retroduction refers to a logical inference process in which a set of observations are used to come up with the 'most likely explanation' regarding the underlying mechanisms leading to the generation of the observed event or phenomena (cf. Danermark *et al*., *ibid*; Zachariadis *et al*., 2013). Accordingly, the aim in this paper is to use a set of primary data collected through a survey on intersectoral collaborations of doctoral researchers to analyze, retroductively, the relevance of two main alternative theories within ATT thesis in hinting at mechanisms underlying the occurrence of those collaborations. More specifically, it is intended to investigate whether the disciplinary factor is a significant mechanism in patterning the occurrence of doctoral researchers' intersectoral collaborations.

In order to conduct this investigation, the paper uses Becher's categorization of what became known as the *cognitive dimension* in the ATT thesis, in order to classify the departmental affiliations of the surveyed doctoral researchers. The later revision of the same thesis emphasized the role of contextual factors (as opposed to the disciplinary characteristics) in shaping the professional practices of academics. Based on this, and in order to elucidate the causal power of each of these alternative theories (known in the ATT literature as the essentialist versus the social practice view), a statistical model is used in which the contextual factor, represented by the country and university variable, is tested as the moderating variable between the disciplinary (independent) and collaboration (dependent) variables. The rest of this paper is organized as follows; the following part reviews the literature around the ATT thesis. Then the next section elaborates on the paper's hypothesis derived from the chosen theoretical framework. Then the adopted statistical methodology and the collected data are explained. The data analysis follows the methodology section, in which the results are also interpreted. A conclusion part discusses the policy implications and limitations of the study.

Theoretical development

This paper derives its main source of hypothesis development from the literature around the ATT thesis, a thesis that has gained significant empirical backing in the literature due to its

ability to explain the professional behaviour of academic researchers across the multitude of disciplines (cf. Braxton and Hargens, 1996; Alise, 2008; Simpson, 2015). This includes both the strong and the weak essentialist view associated respectively with the earlier and later editions of the thesis. Accordingly, Moghadam-Saman (2019, p. 9) has discussed the ATT thesis as having potential in explaining some of the "real" and "contextual" mechanisms (in a critical realist meaning) underlying the intersectoral collaborations of doctoral researchers.

Taking a more general approach to the issue at stake, there has been abundance of findings in the literature emphasizing the prominence of disciplinary differences regarding the collaborative behaviour of academics (cf. Thune, 2009; Thune *et al*., 2016; D'Este & Iammarino, 2010; D'Este & Fontana, 2007; Perkmann *et al*., 2011; Rentocchini *et al*., 2014; Franco & Haase, 2015; Landry *et al*., 2007; Chikoore *et al*., 2016). These scholarly observations call for taking a theoretical concern on the relation between the characteristics of academic disciplines and the intersectoral interactions of academic researchers, including those of doctoral researchers. Hence, the focus in this section is on the literature that has provided background and foreground for the ATT thesis.

Before the development of the ATT thesis, there has been also some other scholarly attempts to categorize academic and scientific disciplines into distinct groups. Braxton and Hargens (1996) mention a number of usually dichotomous conceptualisations of disciplines during the twentieth century, including theoretical vs. empirical fields (Conant, 1951), restricted vs. unrestricted fields (Pantin, 1968), mature-effective vs. immature-ineffective fields (Ravetz, 1971), and pre-paradigmatic vs. paradigmatic fields (Kuhn, 1962). In an attempt similar to the categorizations used later within the ATT thesis, Storer (1967, 1972) had used the hard/ soft and pure/ applied dichotomies in classifying of disciplines. Biglan's (1973) classification of disciplines was based on three dimensions, namely the dichotomies of hard/ soft disciplines, pure/ applied disciplines, and life/ non-life disciplines. In other words, two of the three dimensions proposed by Biglan (*ibid*) where in accordance to Storer's suggestions, even though his references indicate his unawareness about Storer's work. Nevertheless, Biglan found the hard/ soft distinction to be the strongest dimension among the three dichotomies, and the life/ non-life distinction to be the weakest. In fact, the life/ non-life dimension is rarely used by researchers examining variations in teaching and learning (Nelson Laird *et al*., 2008).

Soon after the publication of Biglan's classification, scholars put it through validating queries. Notably, Smart and Elton (1975) used goal orientation of academic departments to test Biglan's model. Their study approved the distinctions made within each pair in Biglan's three suggested

dimensions. Also Creswell and Bean (1981) used the Biglan model on the issues of research output and sources of faculty funding, and found that all the three dimensions in Biglan's classification are important and can explain the variety across the disciplines accordingly. However, Creswell and Roskens (1981), and Smart and McLaughlin (1978) found a strong support only for the significance of hard/ soft and pure/ applied dimensions. Also, Smart and Elton (1982) used a wider set of research measures in a more diverse sample of faculties to examine the validity of Biglan's model, resulting in approval of the three dichotomous distinctions again, although the life/ non-life dimension proved to have a low significance.

At the same time, Becher (1981) had introduced the dichotomy of urban versus rural disciplines, mainly based on their undertaking of rationalistic versus holistic research styles, respectively. While in the urban group, problems would be analyzed by being broken down into smaller areas of inquiry, in the rural group, a holistic approach drives the line of inquiry. Later, Becher added that the urban fields demonstrate a high ratio of researchers to research problems, while rural fields exhibit the opposite. Then, a few years later, Becher (1984) proposed that there exists a relation between the epistemological characteristics of knowledge fields and the culture (collective behaviour) prevalent among the academics in those fields. Nevertheless, based on Biglan (1973) and Lodahl and Gordon (1972), consequently Becher (1987) classified disciplines only in four groups including hard-pure, hard-applied, soft-pure, and soft-applied. He elaborated on each of them by further describing them in terms of the nature of knowledge – according to which the aforementioned four groups were respectively described as being cumulative, purposive, reiterative, and functional – and the nature of disciplinary culture – according to which they were respectively described as competitive, entrepreneurial, individualistic, and outward-looking.

The implication of acknowledging such a relation between the nature of knowledge and disciplinary culture for the external engagements of academics would then be an area for policy contemplation. This is due to the fact that the differences in the knowledge areas' structures would call for different policy approaches to deal with different disciplinary cultures. Becher (1994, p. 6) himself describes such discrepancies in the following paragraph;

> A comparable contrast can be observed between different disciplinary groups in relation to contract research, where departments in hard applied and soft applied areas are able to earn substantial funds by undertaking sponsored work, while faculty in hard pure areas tend to see this as low-status activity, and others against in soft pure domains seldom have any opportunity to contemplate the choice. The consequences in terms of academic working lives

> are evident enough. Those who involve themselves in such activities necessarily have closer contacts with the outside world, which they are able to exploit in a variety of ways, including offering their graduates a wider range of job opportunities and using additional earnings to improve departmental resources.

As it reads from this excerpt, Becher considers the exposure level of each of the disciplinary groups in his model to 'contract research' to be substantially different. Such a discrepancy among these groups would imply significantly different level of opportunity for doctoral researchers in terms of external engagements. Therefore the ATT thesis habors a potential to explain the 'real' structure underlying the occurrence of intersectoral collaborations by doctoral researchers.

Becher's (1989) book constituted the first edition of the ATT thesis, according to which the knowledge structure of disciplines significantly influence the behaviour of academics, and specifically their research practices. According to this original edition of the thesis, the knowledge structure (the epistemological core) of disciplines have a cognitive and a social dimension. The cognitive dimension, in accordance with earlier works by Kolb (1981) and Biglan (1973) divides disciplines into hard-pure, hard-applied, soft-pure, and soft-applied ones. These divisions are also identified respectively with natural sciences, science-based professions, humanities and social sciences, and social professions (Becher, 1994). Also Neuman *et al*. (2002) clustered academic disciplines into the above-mentioned four categories, and referred to it as 'Becher-Biglan typology'.

Becher himself had also earlier distinguished a social dimension for disciplines, which refers to the group identity within each discipline in terms of consensus on the definitions and research problems (questions). Accordingly, he described members of academic disciplines as *tribes* to indicate their cultural foundation. He also used the term *territories* to refer to the boundaries of disciplines to which every tribe belongs. In relation to this, Becher (1989) added a convergent-divergent continuum to the urban-rural continuum, in which convergent disciplines are those in which there is a more clear sense of group identity among the academicians, while divergent ones lack such a clear identity due to having less well-defined disciplinary territories.

Becher and Trowler's (2001) book then utilized Becher's both 1987 and 1989 classifications, calling the former one the cognitive dimension, and the latter one the social dimension of disciplinary cultures. Nevertheless, in this book, which became the second edition of the ATT thesis, the authors point to the changes in the higher education environment that had taken place

since the publication of the first book, and its influence on the significance of disciplinary cultures. The authors posited that the disciplinary cultures had evolved to have less influence on the organizational structures, as the mode of knowledge production had started to change to the one in which problem-orientedness and transdisciplinarity are on the rise (termed as *Mode 2* knowledge by Gibbons *et al*., 1994). Furthermore, the book highlighted the influence on the disciplinary cultures from the increasing linkages between university, industry and government in the form of 'triple helix' configurations. Also contextual influence on the institutions were given more emphasis, rejecting the idea that disciplinary values trickle-down from the leading departments to the "followers" in other universities. The authors made it clear that in this book the academic communities with common intellectual interest are examined in relation to the social and cognitive *contexts* in which they operate.

Still discontent with the continued essentialist view in the second edition, later Trowler (2008) rejected the epistemological essentialist view, starting to develop an alternative approach emphasizing the significance of context and history in understanding social practices. This alternative approach was further elaborated in the third book on the ATT thesis, edited by Trowler, Saunders and Bamber (2012). In this book, the essentialist view predominating the earlier two books on the thesis, was replaced with a *social practice* approach about research practices across disciplines. In this approach, disciplines are seen as open systems susceptible to be influenced by context-specific social characteristics as well as agential and managerialist practices.

As mentioned earlier, the studies aiming at testing the explanatory power of disciplinary categories started already in the 1970s. The scholarly works trying to validate the Biglan classification of disciplines can be categorized into three groups, in which they test Biglan model; 1) across diverse higher educational institutional settings, 2) across broader variety of disciplines compared to the original work, and 3) with regards to particular aspects of disciplinarity (Braxton and Hargens, 1996, cited by Alise, 2008). Braxton and Hargens (*ibid*, p. 8) themselves question whether the social dimension in Becher's classification is "[…] associated with important scholarly phenomena independently from the associations of the phenomena with the Biglan hard-soft and pure-applied dimensions". They conclude from their survey that the levels of scholarly consensus can explain most of the disciplinary differences. Nevertheless, the authors note that according to their preliminary evidence, the level of consensus, as well as the paradigm development concept, can be integrated with the hard/ soft dimensions. As Creamer (2003, p. 3) puts it briefly, "[r]ates of collaboration are higher in what

Biglan (1973) characterized as hard-pure fields where strong agreement exists among faculty about dominant paradigms than in soft-applied fields where there is considerably less consensus about dominant paradigms." She also notes Austin and Baldwin's (1991) findings that such collaborations are more common when the inquiry aim is testing rather than building a theory.

Jones (2012) contends that all of the classification schemes reviewed by Braxton and Hargens (*ibid*) are based upon the view that disciplines have different levels of paradigmatic development due to the level of consensus among their practitioners on issues such as appropriate research topics and methods. Jones then summarizes research examining variation in academic disciplines published after 1996, including both conceptualization attempts and empirical assessments. He finds, however, that most of these have implemented Biglan (1973) model or Smart *et al*.'s (2000) theory. All in all, he concludes that classification schemes developed before 1996 have been found by the higher education research community to be adequate. One of such confirmatory studies was conducted by Alise (2008) who compared a group of pure disciplines with a group of applied disciplines within the social and behavioral sciences, finding supportive results about the validity of the Biglan scheme regarding the difference in preferred research methodology within each group. These include research design (qualitative and quantitative designs), sampling methods (convenience and purposive sampling), and data collection methods (open and unstructured versus secondary data).

Nevertheless, there can be found more moderate positions taken within the literature regarding the relevance of essentialist view within the ATT thesis. For instance, Pinheiro *et al*. (2012) surveyed academics from 19 departments, which were categorized according to Becher's 1994 four groups of disciplines, investigating their external engagement and its nature and benefits. They conclude, however, that despite the advantages of Becher's categorization of knowledge domains in terms of general patterns of behaviour across organizational settings, the neglect of immediate context, such as national and organizational settings in which academic communities function, can be considered as a shortcoming. In this regard, the authors find their argument to be rather in line with Trowler *et al*.'s (2012) argument for 'weak essentialism'.

Research hypotheses

The review presented in the previous section indicates that, having undergone a significant revision, the ATT thesis can be considered as containing what in critical realism terms can be referred to as the alternative proto-theories about the mechanisms underlying the actual phenomena (see Moghadam-Saman, 2019, p. 9). In other words, the epistemological essentialist

view and the social practice view, which constitute, respectively, the essence of the earlier and the later versions of the ATT thesis, propose two alternative understandings about the deterministic power of disciplines in shaping the research activities of academics - including the intersectoral research collaborations of doctoral candidates. The empirical corroboration of those alternative theories, aiming at retroductive inference - in a critical realist account - about the external engagement of doctoral candidates, aims at ensuring that the proposed mechanisms adequately represent the real causality (cf. Wynn and Williams, 2012).

The two alternative versions of the ATT thesis can be read through the following substitutive approaches by two of the key figures in the development of the thesis. Firstly, the earlier version of the thesis can be well understood from Becher's (1994, p. 3) held view, stating that;

> Disciplinary cultures, in virtually all fields, transcend the institutional boundaries within any given system. In many, but not all, instances they also span national boundaries. That this is the case can be seen through the existence of national, and often international, subject associations which embody collective norms and exercise an informal control on undergraduate and graduate curricula, as well as providing a shared context for research.

As it can be understood from this excerpt, Becher considered the disciplinary cultures not to be much context-bound, even across *countries*. Accordingly, disciplines can be perceived as playing the role of what in critical realist accounts can be called the "real" structure underlying the mechanisms shaping the academics' professional culture and behaviour.

As mentioned in the theoretical development section, together with Becher, Trowler wrote the second book on the ATT thesis, which was still largely in agreement with the epistemological essentialist view of disciplines. Nevertheless, Trowler, who pursued developing the later revision of the ATT thesis, shifted his view later, contending that the role of the disciplines is significantly influenced by the context. It can be said that according to this view, disciplines are considered as constituting a 'transitive' mechanism, meaning that the human 'agency', which is in a mutual interactive relation with its surrounding 'structures', significantly mediates and modifies the causal effect of disciplines. In line with this, Trowler (2008) uses the notion of teaching and learning regimes (TLRs) in order to deconstruct, among the multitude of contextual aspects, those most intimately relevant to the disciplinary practices. In his view, "[…] context is the territory in which disciplines are performed" (Trowler, *ibid*, p. 8).

These two alternative understandings of the ATT thesis provide us with a basis for starting what in Danermark *et al*.'s six-step Explanatory Model of Social Science is referred to as the

retroduction step (the fourth step), during which the candidate mechanisms underlying the concerned event – here, the intersectoral collaboration of doctoral researchers - are identified[2]. Consequent to this step comes the comparison of the relative explanatory power of the alternative theories and their respective constituent mechanisms (the fifth step in Danermark *et al*.'s model). What will follow this step, i.e. Danermark *et al*. model's sixth step, termed as *concretization and contextualization*, will complete the empirical corroboration to "[…] enhance our descriptions and understanding of the specific contextual conditions under which these mechanisms were enacted." (Wynn and Williams, 2012, p. 15). However, this last step is out of the scope of this paper, as this paper aims only to enquire on whether the epistemological essentialist understanding of academic disciplines, as conceived within the earlier version of the ATT thesis, can explain the patterns of intersectoral engagement for doctoral researchers across different disciplinary groups from different university and country contexts (see again the aforementioned quote from Becher, 1994). This approach, i.e. testing the presence of a specific, retroductively-inferred mechanism, is also in accordance with Miller and Tsang's (2010) approach in theory testing within critical realism. These authors suggest a four-step approach in a CR-based theory testing (in the field of management), which includes *specifying the hypothesized mechanisms*, *testing for the presence of these mechanisms*, *determining whether they function as hypothesized*, and *testing the full theoretical system*. Accordingly, here we address the second and third step in Miller and Tsang's approach by testing for the presence of disciplinary mechanism at the level of "real structures" underlying the mechanisms causing the "event" of intersectoral research collaboration by doctoral researchers, in order to determine whether it functions as hypothesized by the earlier or latter versions of the ATT thesis. Accordingly, the following hypotheses are put forward for verification by the empirical data:

Proposition: The cognitive dimension of academic disciplines, as defined in the Becher-Biglan typology, function as a significant influencer of the prevalence of intersectoral engagement by doctoral researchers, and remains significant across countries and universities.

Accordingly, the null hypotheses and the alternative hypotheses to be tested by the empirical data are formulated as the followings;

[2] The three steps preceding this step, which include *1- description of events, 2- identification of key components or dimensions, 3- theoretical redescription (abduction) of components or dimensions*, are elaborated in Moghadam-saman (2019).

Null hypothesis 1: The nature of the cognitive dimension of disciplines does not significantly affect the prevalence of intersectoral engagements by doctoral researchers.

Alternative hypothesis 1: The prevalence of intersectoral engagement by doctoral researchers is significantly affected by the nature of the cognitive dimension of their academic disciplines.

Null hypothesis 2: The country or university context does not significantly mediate the extent to which the nature of academic disciplines affect the prevalence of intersectoral engagements by doctoral researchers.

Alternative hypothesis 2: The impact of academic disciplines on the prevalence of intersectoral engagement by doctoral researchers is significantly mediated by the country or university where the collaboration takes place.

It is necessary to note that, under the critical realist paradigm, an explanation would be complete when it addresses all the three points of a) structures underlying the generative mechanism; b) the outcome these mechanisms tend to generate; and c) the contextual elements that influence the actualization of those generative mechanisms (Cartwright, 2003). The above hypotheses, however, are defined to test one theory regarding only the first of these explanation parts. The way the contextual elements interact with the generative mechanism (the disciplinary effect), and the outcome of these for doctoral researchers, is left out of the scope of this paper, as within critical realism it is arguably preferred to address the complex issue of interaction between contextual and intransitive mechanisms to qualitative studies (Danermark *et al*., 2002).

Methodology and data

Following the hypotheses developed in the previous section for testing, hereunder the variables of interest, the data analysis method corresponding to the questions emanating from the hypotheses, and some descriptive features of the data attained through the survey of doctoral researchers in the four Scandinavian universities will be presented. It is noteworthy to mention that, under the critical realist paradigm, the econometric models are deemed as able to reveal only some stylized facts, known as *demi-regularities* as suggested by Lawson (1997). This means that the hypotheses tested mainly concern the context from which the data are derived, rather than providing a basis for positivist-style generalizations of the findings.

The dependent variable

The dependent variable in this study is to indicate whether doctoral researchers in the sample are – or will be – engaged with the non-academic sectors during their doctoral education. Therefore, the dependent variable is a dummy variable.

Alise (2008) chose to use data on what affiliates of academic disciplines actually *do* (research), rather than *say*, in validating 'Biglan classification'. Similarly, this paper uses the actual occurrence of intersectoral collaborations for the studied doctoral researchers (the empirical layer in the CR ontology) to validate the explanatory power of the ATT thesis (in the form of either of its two versions) regarding the causality potential between disciplines (the layer of real in the CR ontology) and the intersectoral collaborations of doctoral researchers. This will in fact enable the retroductive logic to assess, and if necessary, refine the theories around the underlying mechanisms (the layer of 'real' in the critical realist ontology) which lead to the generation of the actual events (here, the occurrence of intersectoral collaborations for the doctoral researchers). Bozeman and Gaughan (2007) show that grants and contracts from industry and government have a significant effect on academic researchers' propensity to work with industry, albeit the effect from the latter is more moderate. In this paper, collaborations with both private and public sector industry have been included under the overall title of intersectoral collaboration between the academic and non-academic sectors.

The independent variables

Corresponding to the queries raised in the two hypotheses, the two explanatory variables include the disciplinary group to which the doctoral candidates in the sample belong to, and the country and university in which they conduct their doctoral studies. Similar to Robles (1998) and Roy (1979) who equates disciplines with departments in campuses, and Pinheiro *et al*. (2012) who categorize departmental units of a university into the four quadrants of Becher's typology, the disciplinary affiliations of doctoral candidates are here coded into one of the four categories in Becher-Biglan's Typology (see also Neuman *et al*., 2002) based on their departmental affiliation. This coding was done by using the following definitions used by Neuman *et al*. (*ibid*, p. 406) regarding each of the categories in the cognitive dimension of disciplines;

- *Hard Pure*: The nature of knowledge in these disciplines has "cumulative, atomistic structure, concerned with universals, simplification and quantitative emphasis." Examples: physics, chemistry, mathematics, biology.

- *Hard Applied*: The nature of knowledge in these disciplines is "concerned with mastery of physical environment and geared towards products and techniques." Examples: technology, engineering, medicine, design.
- *Soft Pure*: The nature of knowledge in these disciplines has "reiterative, holistic, concerned with particulars and having a qualitative bias." Examples: history, literature, art theory, sociology.
- *Soft Applied*: The nature of knowledge in these disciplines is "concerned with the enhancement of professional practice and aiming to yield protocols and procedures." Examples: education, business studies, law, information management.

Then, in order to investigate the second hypothesis, the country and university in which the doctoral candidates are conducting their studies are coded in the form of a categorical variable.

All in all, from a population of 4213 doctoral researchers in the four universities, a total of 587 responses were received, resulting in a response rate of 13.93%. Per university, the response rates ranged from 8.65% in the case of Gothenburg University to 24.24% in the case of University of Stavanger. Table 1 shows the response rate from each university.

Table 1 – Response rate from each of the four universities participating in the survey.

University*	**UiS**	**LiU**	**GU**	**AAU**
Total number of doctoral researchers	425	1219	1710	859
Total number of responses	103	140	148	196
Response rate	24.24%	11.48%	8.65%	22.28%

*UiS: University of Stavanger, LiU: Linköping University, GU: Gothenburg University, AAU: Aalborg University

Not only in sum, but also in each individual university, the highest number of responses came from doctoral researchers affiliated with hard-applied (HA) category of disciplines. Table 2 shows the number of responses from doctoral researchers in each university under each category of disciplines.

Table 2 – Total number of responses from doctoral researchers affiliated with each of the four disciplinary groups at each university.

the name of the university	cognitive dimension				
	HA	HP	SA	SP	Total
Linköping University	52	21	32	35	140
University of Aalborg	141	13	12	30	196
University of Gothenb	80	15	20	33	148
University of Stavang	35	14	24	30	103
Total	308	63	88	128	587

Pearson chi2(9) = 61.5089 Pr = 0.000

The total number of observations for either situation of the dependent variable in terms of the frequencies under each category of disciplines are demonstrated in Table 3. It shows that for all the disciplinary groups, *not* being involved in an intersectoral collaboration is more prevalent, although such a difference is much more pronounced in the case of 'pure' groups of disciplines compared to the 'applied' groups (in both hard and soft disciplines).

Table 3 – Total number of responses from doctoral researchers affiliated with each of the four disciplinary groups at each university, in terms of having or not having intersectoral collaboration*.

intersectoral collaboration	cognitive dimension HA	HP	SA	SP	Total
0	185	47	49	93	374
N	123	16	39	35	213
Total	308	63	88	128	587

Pearson chi2(3) = 11.8880 Pr = 0.008

* 0: with no intersectoral collaboration, N: with intersectoral collaboration

If we distinguish between the co-funded and not-co-funded intersectoral collaborations, we see that in all the disciplinary categories, not-co-funded collaborations outnumber the co-funded ones, although such a difference seems to be more pronounced in the 'soft' group of disciplines compared to the 'hard' groups (for both pure and applied disciplines).

Table 4 - Total number of responses from doctoral researchers affiliated with each of the four disciplinary groups at each university, in terms of having or not having their collaboration co-funded**.

collaboration and funding	cognitive dimension HA	HP	SA	SP	Total
NN	185	47	49	93	374
YN	79	10	31	26	146
YY	44	6	8	9	67
Total	308	63	88	128	587

Pearson chi2(6) = 16.2963 Pr = 0.012

** NN: no collaboration and no funding, YN: collaboration with no (co)funding from the collaborating non-academic entity, YY: collaboration with (co)funding from the collaborating non-academic entity

While these descriptive statistics indicated in the Table 3 and 4 already hint at a potentially significant "patterning effect" of disciplinary groups, the data analysis in the next section aims at providing a more robust (although not *strict*) regularities in the occurrence of collaborations. In other words, the aim is to identify important demi-regularities which can help direct the overall research process in its quest for identification of causal mechanisms later in the qualitative (intensive) study (Lawson, 1997).

Data analysis and interpretation of results

Stata software was used in order to conduct the data analysis for this research paper. The data from the survey of doctoral researchers was stored in spreadsheet format and after coding the data according to the afore-mentioned categorizations - based on departmental affiliations - was transferred (imported) to Stata. All the independent variables were then "encoded" as categorical variables. The dependent variable, i.e. the existence of intersectoral collaboration, was coded as a dummy variable.

Model specification

To run the logistic regression, Stata's *logit* command was used. Since the dependent variable is a dummy (indicating existence or non-existence of intersectoral collaboration) and the independent variables are of indicator (categorical) type, and the moderation effect is also included, the Stata command was specified as in the Tables 5 and 6.

In these tables, the variable cllb denotes the outcome variable which indicates whether the doctoral researcher has a collaboration with non-academic sectors (could be with public sector, with private sector, or both). The variable i.ctry denotes the categorical variable of country where the doctoral student is based, and the variable i.cogn refers to the category of cognitive dimension of academic discipline according to Becher-Biglan's categorization. The variable i.ctry#i.cogn denotes the moderation effect of country on the pattern-giving effect of disciplinary groups being tested by the analysis.

In order to check whether the case of two Swedish universities makes a difference in the results, the analysis was done once more with using university as the mediating variable (see Table 6). Here, the variable ib2.univ includes the variable denoting the categorical variable of university (i.univ), in which b2 was used to change the base (reference) category into Aalborg University in order to make the results comparable with the previous analysis, where Denmark was the base category for the country variable (which in this case also represented the single university from Denmark).

Model identification and parameter estimation

Table 5 depicts the results gained from Stata after running the aforementioned logit command for specifying the analysis model. As it can be seen from the initial part of the results, the model has merged after four iterations. The likelihood ratio chi-square of 38.86 with a p-value = 0.0001 tells us that our model as a whole fits significantly better than an empty model (i.e., a

model with no predictors), or in other words, at least one of the regression coefficients in the model is not equal to zero. The results also showed McFadden's pseudo R-squared value equal to 0.0479, indicating a good fit (Hemmert *et al*., 2018).

Table 5 – The results attained from the logit model with country as moderating variable.
. logit cllb i.cogn i.ctry#i.cogn

cllb	Coef.	Std. Err.	z	P> | z |	[95% Conf. Interval]	
cogn						
HP	-1.07	0.68	-1.58	0.113	-2.41	0.26
SA	-0.21	0.61	-0.34	0.732	-1.40	0.99
SP	0.13	0.40	0.32	0.751	-0.66	0.92
ctry#cogn						
Norway#HA	-0.40	0.39	-1.03	0.305	-1.16	0.36
Norway#HP	0.92	0.85	1.08	0.282	-0.75	2.59
Norway#SA	-0.76	0.75	1.76	0.311	-2.24	0.71
Norway#SP	-1.87	0.65	1.55	0.004**	-3.14	-0.60
Sweden#HA	-0.57	0.25	-2.26	0.024*	-1.06	-0.08
Sweden#HP	-0.22	0.78	-0.28	0.781	-1.75	1.31
Sweden#SA	0.49	0.65	0.76	0.449	-0.78	1.76
Sweden#SP	-1.18	0.46	-2.54	0.011*	-2.09	-0.27
cons.	-0.13	0.17	-0.76	0.449	-0.46	0.20

The output of the two logit models compare respectively two and three groups of the doctoral students with the reference group. In the top section of the both of the output tables, the reference group comprises those doctoral researchers who are affiliated with the hard-applied group of disciplines. By default, Stata chooses the most frequently occurring group to be the reference group, which as indicated earlier, in our sample comprises of hard-applied group. The top section of the output table compares with the base group the other disciplinary groups, i.e. those who are affiliated with hard-pure, soft-applied, and soft-pure disciplines. What matters in the case of this research are the p-values in order to see whether the disciplinary groups matter regarding the probability of having intersectoral collaborations. The co-efficients are hence reported solely for the sake of transparency.

In the bottom section of the both tables, the reference group comprises those doctoral researchers who are affiliated with the Aalborg University in Denmark. Hence, the bottom part of the first output table, compares with the base group the doctoral researchers from other two countries, i.e. those who are conducting their doctoral studies in the two universities in Sweden and the University of Stavanger in Norway. In the second table, the bottom section makes a distinction in the Swedish sample between the observations at the GU and LiU.

Arguing about the view of critical realism to regression analysis, Ron (2002, p. 3) holds the position that "[t]he gist of successful regression analysis is not to be able to offer a law-like statement, but to bring forth evidence of an otherwise hidden mechanism". In line with this, he

posits that unlike the empiricist interpretation of regression analysis, which uses this method for identifying law-like *regularities* in the observed phenomena, the critical realist interpretation of regression analysis assume the role of isolating the *mechanism* emanating from the real *tendencies* of underlying structures (here, the epistemic core of disciplines).

Table 6 – The results attained from the logit model with university as moderating variable.
. logit cllb i.cogn ib2.univ#i.cogn

cllb	Coef.	Std. Err.	z	P> | z |	[95% Conf. Interval]	
cogn						
HP	-1.07	0.68	-1.58	0.113	-2.41	0.26
SA	-0.21	0.61	-0.34	0.732	-1.40	0.99
SP	0.13	0.40	0.32	0.751	-0.66	0.92
univ#cogn						
Linköping University#HA	-0.26	0.33	-0.79	0.427	-0.91	0.38
Linköping University#HP	0.04	0.83	0.05	0.961	-1.59	1.68
Linköping University#SA	1.27	0.71	1.81	0.071	-0.11	2.66
Linköping University#SP	-1.06	0.53	-1.99	0.046*	-2.10	-0.02
University of Gothenburg#HA	-0.78	0.30	-2.61	0.009**	-1.37	-0.19
University of Gothenburg#HP	-0.67	1.01	-0.66	0.506	-2.64	1.30
University of Gothenburg#SA	0.76	0.78	-0.98	0.329	-2.29	0.77
University of Gothenburg#SP	-1.31	0.56	-2.34	0.019*	-2.41	-0.21
University of Stavanger#HA	-0.40	0.39	-1.03	0.305	-1.15	0.36
University of Stavanger#HP	0.92	0.85	1.08	0.282	-0.75	2.59
University of Stavanger#SA	-0.76	0.75	-1.01	0.311	-2.24	0.71
University of Stavanger#SP	-1.87	0.65	-2.88	0.004**	-3.14	-0.60
cons.	-0.13	0.17	-0.76	0.449	-0.46	0.20

This means that the causal influence of underlying unobservable structures only *tends* to lead to certain patterns, but this might not always actualize as other, contextual mechanisms can hinder that influence. In agreement with this view, the findings from the data analysis in this paper can be interpreted as follows.

- *Essentiality of disciplines' cognitive dimension for doctoral researchers' intersectoral engagements*

The results from the logit model shows that in general, for comparing intersectoral collaboration opportunities of doctoral researchers affiliated with hard-pure, soft-applied, and soft-pure disciplines relative to those affiliated with hard-applied disciplines, the essentialist view cannot explain the differences. The outputs of the logit model shows that the z test statistic for the predictor hard-pure (-1.08/0.68) is -1.58 with an associated p-value of 0.113. If we set the alpha level to 0.05, we would not be able to reject the null hypothesis 1, and hence conclude that the difference between doctoral researchers affiliated with hard-applied and hard-pure disciplines has been found not to be statistically significantly different. Similarly, since the p-values for the soft-applied and soft-pure disciplines are 0.732 and 0.751 respectively, the difference between the intersectoral collaborations of doctoral researchers affiliated with these groups of

disciplinary cognitive dimension and the hard-applied group is not significant. Hence, the cognitive dimension of disciplines proves not to be an important factor in determining the pattern of intersectoral collaborations of doctoral researchers.

- *Intersectoral engagements of doctoral researchers in LiU, GU and UiS, relative to AAU*

Despite the general findings regarding the non-suitability of essentialist view of disciplines in describing the intersectoral collaboration opportunities of doctoral researchers in the sample, further breakdown of the sample to doctoral researchers from each of the countries and universities provides a further nuance to the above-mentioned general finding.

For those doctoral researchers in Norway whose academic discipline is in the hard-applied category, compared to the respective reference group, i.e. those affiliated with hard-applied disciplines in the Danish sample, the z test statistic for the predictor Norway#HA (or University of Stavanger#HA in the second table) is -1.03, with an associated p-value of 0.305. By setting the alpha level to 0.05, we fail to reject the null hypothesis 2. In other words, we cannot reject that compared to the base country (Denmark), the prevalence of intersectoral engagement of doctoral researchers from hard-applied disciplines is not significantly different in Norway. However, the same argument does not apply to the case of doctoral students from hard-applied disciplines in Sweden, according to the respective p-value (0.024). Therefore, the results of the logit model imply that when it comes to the hard-applied disciplines, the contextual factors implicit in the country variable do matter in determining the intersectoral collaboration opportunities of doctoral researchers.

Then, according to the output of the logit model in the first table, the prevalence of engagement with non-academic sectors for doctoral researchers from hard-pure and soft-applied disciplines in Norway and Sweden is significantly different from that of their peers in Denmark. Concerning HP disciplines, doctoral researchers' intersectoral collaboration opportunities in Norway and Sweden are not significantly different from those in Denmark (given p=0.282, p=0.781, respectively), thus we cannot reject the null hypothesis 2. Similarly, according to the second table too, the p-values for the SA and HP disciplines for all the three universities compared to the base university are greater than 0.05.

And when it comes to the doctoral researchers from soft-pure disciplines, in the first table for both Norway and Sweden the prevalence of intersectoral engagement is significantly different from Denmark (indicated by p-values of 0.004 and 0.011). Also in the second table, all the p-values for the three universities compared to the AAU, are smaller than 0.05 (0.046, 0.019 and

0.004). Therefore, in the case of doctoral students affiliated to soft-pure disciplines, the null hypothesis can be rejected, implying that the prevalence of intersectoral collaborations, even in the relatively similar context of Nordic countries, varies by the country and university context. This result implies that soft-pure disciplines are - specifically concerning the issue of intersectoral collaborations – (socially) practiced differently, making the opportunities for intersectoral collaboration significantly influenced by the contextual factors.

Conclusion and implications

Citing the example of grant-getting and student recruitment, Trowler (2008, p. 6) notes that being able to make distinctions among disciplines regarding their power to condition policy and practice "[…] is important for institutional management, particularly at a time when managerialist approaches are predominant". In agreement with this view, it was the aim of this paper to assess whether the academic disciplinary specifics can explain the differences in prevalence of intersectoral research collaborations among doctoral candidates. In doing so, the two alternative versions of Academic Tribes and Territories thesis were considered as substitutive views in terms of the extent of importance attached to the pattern-giving power of disciplines. The original version of the ATT thesis, known as the essentialist view, implies that intersectoral engagements are largely determined by the disciplinary groups since their epistemic core strongly influences the collaboration opportunities. The revised version of the ATT thesis, dubbed as social practice view, contends that the influence of disciplines is conditioned by the societal setting where the discipline is practiced. The analysis was hence intended to understand which of the views within the ATT thesis, as two proto-theories, are better able to explain the patterns of intersectoral collaborations by doctoral researchers from the four Nordic universities. While the earlier version of the ATT thesis implies that the intersectoral collaborations of doctoral researchers are highly determined by their disciplinary category (or more precisely, its cognitive dimension), the latter version of the ATT thesis implies that the disciplinary effect on those collaborations is mediated by the context in which those disciplines are practiced. The results gained from a survey of doctoral researchers from the four universities in three Nordic countries, however, demonstrates that the answer to the above-mentioned question depends on the specific categories of the disciplinary groups. In other words, each of the essentialist- and social practice-based interpretations of the ATT thesis prove to have more explanatory power for some of the four disciplinary groups.

Based on the above, and similar to the notion of Teaching and Learning Regimes (TLRs) used by Trowler (2002), in this paper the notion of 'regimes of intersectoral engagement' is

proposed, based on the attained results, to denote the witnessed difference between the theories applicable to the disciplinary groups. Accordingly, while the *essentialist regime* of intersectoral engagements better corresponds to hard-pure and soft-applied disciplines, the *social practice regime* of intersectoral engagement seems to better explain the engagement opportunities of doctoral candidates within hard-applied and soft-pure disciplines. Hence, HA and SP disciplines are more susceptible to be influenced by getting combined with causal tendencies that emerge as a result of interaction between the disciplinary and contextual factors around the external engagements of doctoral researchers.

A research implication of this approach would be that, in determining the factors important in improving the intersectoral collaborations by doctoral candidates affiliated with HA and SP disciplines, scrutiny is needed in uncovering the contextual mechanisms able to affect the causal power of the epistemic core of these disciplines. For instance, further research should investigate how doctoral programmes defined around specific academic disciplines from these disciplinary groups interact differently in different country- or university contexts with regulatory or policy elements around the issue of intersectoral collaboration.

On the other hand, according to the findings of the paper, for those doctoral candidates affiliated with the soft-applied and hard-pure disciplines, disciplinary characteristics are strong determinants, as the contextual variation seems not to be significantly changing the collaboration opportunity. Accordingly, it can be argued that, for improving the intersectoral collaboration opportunities of those affiliated with these disciplines, it is of higher relevance to introduce interdisciplinarity within the research and education curricula, as the epistemic core of these disciplines seem to be specifically crucial in shaping their potential for providing engagement opportunities. For instance, improving intersectoral collaboration opportunity for doctoral candidates within the field of business administration or mathematics can be achieved through strengthening their knowledge communicability with engineering fields.

A policy implication of the findings of this paper is that, when it comes to the measures aiming at promoting the intersectoral collaborations of doctoral researchers, a distinction shall be made between the disciplinary groups regarding the extent to which their potential for providing opportunity for collaborations are affected by the contextual elements. The results from this study implies that, even in a relatively homogeneous higher education context like the Scandinavian countries of Norway, Denmark and Sweden, the propensity of soft-pure disciplines for intersectoral collaborations of doctoral researchers varies significantly across country and university contexts. Similarly, but to a lesser extent, hard-applied disciplines are

also showing a sensitivity to contextual conditions for providing intersectoral collaboration opportunities. Hence, policies aiming at the increase in the level of intersectoral collaborations during doctoral education in these categories of academic disciplines need to be tailored in accordance with the way such disciplines are "practiced" in those contexts.

Following the critical realist epistemology, the findings of this paper need to be understood as ideal-typical middle-range hypotheses (Smith, 2010). This consideration is specifically related to the data sources which were confined within the Nordic context. This means that the proposition that regimes of engagement are disciplinary-group-driven, and their specific types of regime (essentialist or social practice based) can be further refines through research with data from other contexts. Nevertheless, concerning the studied contexts, as indicated by the results, the HA and SP disciplines appear to be more prone to the influence of contextual specificities, implying that the attained data regarding the intersectoral collaborations of doctoral candidates affiliated with these disciplines can be subject to the specifics of Nordic higher education systems and their industry collaboration traditions. More specifically, the higher prevalence of triple helix collaborations in some of these countries can indicate that university-industry collaborations have higher probability to provide opportunities for doctoral candidates' engagement with industry. Furthermore, the collaboration policies of universities represented by the data in this study add another contextual conditioning layer (or contextual mechanism, in CR terms), as within the national systems, a variety of third mission policies can be applied by universities, affecting the intersectoral engagement opportunities of doctoral researchers.

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Conflict of interest

The author declares no existence of conflicting interests concerning the content of this paper.

Availability of data and material

The data used for the analysis in this paper are available upon request.

Code availability

The implemented software code for data analysis is available upon request.

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Paper IV

Title: How collaborative doctoral programmes foster the acquisition of generic skills? – Professional Doctorate versus Industrial PhD

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Abstract

Over the recent decades, pursuing a career in industry has been an increasing tendency and necessity among doctoral graduates in developed economies. This has given rise to the establishment of industrial collaborative doctoral programmes that give doctoral candidates opportunity for engagement with industry in order to get better equipped with the skills needed in industry. There has come little insight so far from literature on the experience of doctoral candidates from participation in those collaborative doctoral programmes, however. Aiming to contribute to the filling of this gap, this paper compares the experiences expressed by doctoral candidates participating in two different "industrial" collaborative doctorate programmes with those expressed by doctoral candidates conducting "conventional" doctoral education. The aim is to investigate the candidates' perceived effectiveness of such programmes on the development of their generic (transferable) skills. Implementing a mixed-methods approach under the critical realist research paradigm, the study results indicate that doctoral candidates' perception about the effectiveness of industrial collaborative doctoral programmes for generic skills acquisition is higher than their peers doing a conventional doctorate, when they also have positive perceptions about disciplinary knowledge improvement through the collaboration. Further inquiry through interviews points to the importance of balanced and concurrent development of disciplinary and generic skills in order for doctoral candidates to experience a more comprehensive and effective acquisition of generic skills. Implications for doctoral education policy and practice conclude the paper.

Keywords: *doctoral education, generic skills, transferable skills, collaborative doctoral programme, Industrial PhD, Professional Doctorate*

Introduction

The recent decades have witnessed an increasing trend of doctoral graduates joining the non-academic labour market (cf. Auriol *et al*., 2013; Bloch *et al*., 2015). Nevertheless, a mismatch can be recognised between the industrial employers' expectations and those of doctorate holders who join industry concerning the employability in industry and the related skills (De Grande *et al*., 2014; Pedersen, 2014). This means that acquisition of skills relevant to the non-academic

professions is gaining more prominence than ever before (Enders, 2004). Concomitantly, the increase in the provision of industrial collaborative doctoral programmes, which supposedly shall positively influence doctoral candidates' preparedness for non-academic careers, is contributing to change their preference in favour of non-academic careers (Gemme, 2005). The change of preferences during postgraduate education in favour of academic career can also take place (Gemme and Gingras, 2011). In fact, the interests and preferences of candidates can change during the course of their doctoral studies based on their characteristics (Sauermann and Roach, 2012). This can imply that, as Mowbray and Halse (2010) have also pointed out, the acquisition of skills in such a way that helps candidates to keep the flexibility towards the future career path is a more sound approach.

Reflecting these issues, doctoral education has in fact evolved in many European countries from being structured in a single model to a variety of models. Kehm (2009) identified eight models of doctorate in Europe, namely the research doctorate, the professional doctorate, the taught doctorate, PhD by published work, the practice-based doctorate, the "new route" doctorate, two models of the joint doctorate, and the industrial doctorate (see also Bao *et al*., 2018, in which cooperative doctorate is also added to this list). Some of these models have emerged more recently and set the doctoral education in a path of becoming a mixture of 'education' and 'training', an approach which according to Pearson *et al*. (2004) contributes to the goal of achieving personal, social and economic benefits at the same time.

One of the main rationales behind the introduction of the newer modes of doctorate is to equip doctoral researchers with skills applicable beyond academe. Barnacle and Dall'Alba (2011) investigated the notion of research degrees as a form of professional education, and noted that a growing emphasis could be found in countries like UK and Australia regarding the training of researchers on generic and transferable skills. Arguing that the employment paths ahead of research graduates are too diverse to be matched with the generic skills development, the authors advocate for embedding those skills development efforts in the inquiry practice and know-how of those researchers. This is in fact in line with what Mowbray and Halse (2010) conclude from their grounded-theory-informed study of skills acquisition by PhD students, which holds the view that intellectual virtues, or domains of knowledge and categories of skills, are not discrete capacities but complementary and interdependent parts of a whole.

Nevertheless, Gilbert *et al*. (2004) point to the mixed responses and appreciations by students and staff regarding generic skills programs, and that there exist a tension between the training versus educational perception of doctorate. Borrell-Damian (2009) mentions that the discussion

on transferable skills has been the most controversial aspect of the DOC-CAREERS survey's dialogue, as there has not been a general agreement on the extent to which those skills need to be a structural element of doctoral education. Furthermore, scholars like Mowbray and Halse (2010) and Craswell (2007) have questioned what they term *skills push* and *employability discourse* for not having a nuanced approach in comprehending the transferability of skills. For Mowbray and Halse, different categories of skills a doctoral candidate can acquire are collectively termed intellectual virtues, and comprise practical knowledge, theoretical knowledge, scientific knowledge, productive knowledge and intuitive knowledge. They assert that such an understanding about the skills acquisition during PhD better captures their "[…] experiences of skills development as a process of acquiring and improving an interdependent suite of skills from a range of contexts that transcend disciplinary boundaries to fashion students' personal and professional growth." (Mowbray and Halse, *ibid*, p. 662).

Then, Craswell (2007) argues for the need for discriminative power when it comes to the employability discourse around higher degree research students. She points to the shortcomings in the notions of skills transferability and embedding, arguing that these notions lack discriminative power. With this, she refers to the nuances and differences found in terms of the degree of embeddedness and transferability of various generic skills. Furthermore, she advocates for research within local contexts (and disaggregated data) informed by higher degree research students' own perceptions about employability skills, feeding the design of the respective training programs. According to her, "[w]hat is needed is research within local contexts—disaggregated data that can usefully feed into the design of training programs for particular HDR [higher degree research] student cohorts, and into decision-making about appropriate delivery methods." (Craswell, 2007, p. 388).

In line with these observations, the research conducted in this paper uses primary data collected from doctoral researchers at two universities, each at a different country context, concerning their experience with skills learning from intersectoral collaborations during their doctoral education. The rest of the paper is organized as follows; drawing on the extant literature, the next section elaborates on the theoretical framework and the research questions. Then, the implemented research methodology is explicated in the light of the chosen research paradigm, supplemented with descriptions about the collected data. Consequently, findings from (quantitative and qualitative) data analyses are presented, which is followed by discussion of the results in accordance with the research paradigm implications. Conclusion part winds up

the paper with pointing out the implications of the findings for policy and practice of doctoral education.

Theoretical framework and research questions

In the extant literature on the careers of doctorate holders, there exists implications to the relations between the disciplinary and contextual factors for the doctoral graduates' career outcome. For instance, highlighting the dissimilar trends between France versus the UK and the US, Lee *et al*. (2010) point to the international differences in career patterns of science and engineering PhD graduates, suggesting that "[…] further research may look into the underlining institutional mechanisms that shape the differences [between their career patterns]." (p. 878). This resonates with the more recent findings by Kim *et al*. (2019) that concluded from their study in the US that a number of university and department factors are relevant in affecting the career choices of science and engineering doctoral graduates, including geographical location and faculty composition, and a program's relative emphasis on traditional academic work versus activities valued in industry. This latter point is in line with more general findings in the higher education literature which posits that pedagogical practices involving collaboration and interaction - as opposed to mere lecturing (cf. Virtanen and Tynjälä, 2019) – and work placement (cf. Crebert *et al*., 2004) better foster the learning of generic skills, which are in turn considered as key to the employability of graduates.

One outstanding issue in the comprehension of the skills acquisition during doctoral education, concerns the interdependency of the generic and disciplinary skills. Bridges (1993) drew a contrast between transferable skills and cross-curricular skills, maintaining that the former relates to the application of skills across different social contexts, while the latter features the applicability across a variety of cognitive domains. In further developments in the literature, scholars such as Kemp and Seagraves (2006) remind us that the research on cognitive development and related cognitive skills (analysis, synthesis, critical thinking, problem-solving) has suggested that these are discipline related. The more recent understanding of the academic disciplines maintains that these are 'socially practiced'[1] (cf. Trowler *et al*., 2012) due to their increasingly heightened exposure to the non-academic actors' role in knowledge production (cf. Gibbons *et al*., 1994). Nevertheless, Moghadam-Saman (*forthcoming*) argues that there can be acknowledged a *regime discrepancy* among academic disciplines with regards to providing opportunity for intersectoral engagement of doctoral candidates; hard-applied

[1] As opposed to the essentialist view of disciplines, which attaches higher importance to the *epistemic core* of disciplines.

disciplines being more susceptible to the influence of contextual differences than soft-applied disciplines, for instance. Consequently, the acknowledgement of interrelations between generic - or transferable – skills and disciplinary skills would imply that for those conducting doctoral studies in hard-applied disciplines – such as engineering – the opportunities for acquiring the generic skills are more context-dependent. Taking a position compatible with the social practice view, Kemp and Seagraves (*ibid*) put to the question whether "transferable skills" are totally context-free and hence totally transferable. Jones (2009) interviewed academics from five different disciplines (from different cognitive categories) regarding the generic attributes, and concluded that these attributes are discipline dependent, as they are shaped by the social practice of the disciplines. As she explicates, "[g]eneric attributes, as part of the social practice of each discourse community, are often not explicitly taught, but rather are picked through the knowledge or concepts under instruction" (*ibid*, p. 94). Referring to Becher's (1989) epistemologies of the disciplinary tribes, Jones asserts that those disciplinary traits "influence concepts which had previously been thought to be generic" (*ibid*, p. 95). Nevertheless, she distinguishes between the generic skills which are more discipline specific, such as problem solving, and those which are less so, such as critical thinking. Finally, she contends that "[t]here are factors other than the discipline which are at work in the construction and teaching of generic attributes. So the disciplinary epistemology, disciplinary traditions, university and departmental culture combine to create a community of practice in which much that is important is also unspoken" (*ibid*, p. 94). Similar to this conclusion, the study by Neumann & Tan (2011) compared employment trends of doctoral graduates from two Australian universities, and demonstrated the importance of disciplinary as well as institutional variations influencing those trends.

As implied by the findings of Lee *et al*. (*ibid*) and Kim *et al*. (*ibid*), the contextual factors can refer to those specific to the national as well as sub-national factors at the regional and university level. Indeed, a similar recognition of multi-level contextualisation of academic practice can also be found in the higher education governance literature, where the importance of two levels of institutional *filters* against the generic university governance reforms across Europe is highlighted, namely a national filter and a sector filter (cf. Gornitzka *et al*., 2017). Accordingly, those generic governance models can be reshaped and adapted by national traditions in public sector governance, and also by established values, attitudes and arrangements in each university within national systems. Then, as asserted by Donina *et al*. (2019), variations in term of university governance models can have implications for the

external engagement activities of the academics. When it comes to doctoral education, then, according to Van Deynze and Santos (2019), in reacting to the institutional pressures from the European entities, differentiations at the national and university level appear based on three modes of engaging and interacting with such pressures, namely channelling, filtering and buffering (avoiding or ignoring) of those pressures.

By viewing doctoral programmes - which are usually regulated and recognised under the national as well as university level regulations - as *mechanisms* embedded in specific higher education system *contexts*, the experience of doctoral candidates in terms of disciplinary and generic skills acquisition can be considered as an *outcome* (see Moghadam-Saman, 2019). However, as mentioned earlier, the heterogeneity of generic skills in terms of their transferability and interrelation with academic disciplines has been argued for in the literature. In an approach useful for such a nuanced understanding of these skills, the classification by González and Wagenaar (2003) categorises general skills into three groups: (i) *instrumental skills* (including cognitive, methodological, technological, and linguistic abilities); (ii) *interpersonal skills* (including social interaction and cooperation, and critical and ethical consciousness); and (iii) *systemic skills* (the ability to analyse the whole and understand how the parts work together, as well as how to combine and apply skills and knowledge to different situations). The authors behold the view that the acquisition of systemic skills require the prior acquisition of skills from the other two group, i.e. the instrumental and interpersonal skills. In harmony with such a typology of generic skills, the institutional context for gaining those skills can be also considered to be multifocal. For this purpose, it is plausible to refer to Drummond *et al*. (1998) who categorised three broad approaches that can be implemented by higher education institutions to develop skills within the academic curriculum. These include; embedded or integrated development, i.e. within the curriculum; parallel (stand-alone) development, i.e. through free-standing modules; and work placements or in work-based projects (practice). Then, whether industrial collaborative types of doctoral programmes, which provide opportunities for engagement with work places outside academic context, can improve the acquisition of all types of generic skills by doctoral researchers, is a question which is sought in this paper. But primarily, and based on the discussions presented regarding the interdependency of skills, the first research question is formulated as follows;

> *RQ1) Does discipline-specific learning from intersectoral collaborations during doctoral education influence the experience of doctoral researchers in acquiring generic skills?*

It is important to note that the question above is not aiming to establish a causal relation between the learning of discipline-specific and generic skills. As the two are, based on the aforementioned discussion, deemed interrelated, it rather looks for uncovering an underlying *mechanism*. In fact, as critical realism is concerned with mechanisms of change, and not law-like causality, the emphasis in this study in on factors which can explain the multicausal process of change (i.e. learning). Moreover, and in harmony with this view, reviews of the literature on PhD careers in industry has shown that, overall, scholarly studies have not obtained significant results from the analysis of demographic variables such as age, gender and marital status (Herrera and Nieto, 2016). These latter authors emphasize the importance of more contextual factors such as firm's activity and location, but also acknowledge that the extant literature has mostly focused on academic factors. An implication of these findings can be that academic factors' effect on PhD careers need to be understood in their confluence with the contextual factors. Consequently, the skills acquisition, if influenced by the disciplinary and institutional backdrops, is conjectured as improvable through well-configured intersectoral programmes potent in actualising the capacities of those two overall factors. The factors driven by the business decisions, such as firm activity type and its location, however, are out of the reach for academe's decision-makers. Nevertheless, as a context-laden mechanism, one important factor of collaborative doctoral programmes in predicting the career paths of PhDs – which *can* be influenced by higher education actors' decisions – can be the *intensity* of the relationship with firms (Recotillet, 2007). This can indicate that the closer intersectoral collaboration during doctoral research period can lead to the better and more efficient acquiring of the skills relevant for career outside academe. In line with this, Borrell-Damian *et al*. (2015) report that *duration* and *committed resources* are the key areas typically covered most when establishing a formal agreement between the partners in a collaborative doctoral schemes. Based on this, the second research question is formulated as follows;

> *RQ2) Does the intensity of collaborative doctoral programmes in terms of duration and funding composition make a difference for acquisition of generic skills?*

As mentioned, the engagement of doctoral researchers with industry, and its outcomes in terms of generic skills acquisition, can be framed, following a critical realist approach, in term of Pawson and Tilley's (1997) Context-Mechanism-Outcome configurations (Moghadam-Saman, 2019). In this *realist evaluation* framework, the aim is to identify the underlying generative mechanisms that could explain how the events (collaborations) were caused, and what is the influence of context on the 'actualisation' (or not) of the causal power of those underlying

generative mechanisms. As a theory-driven evaluation framework, the realist evaluation seeks to describe how an intervention programme (here, industrial collaborative doctoral programme) leads to its outcomes (here, the acquisition of generic skills) and under which conditions (here, the institutional and organisational context in which a collaborative programme is embedded). The initial intervention theory in our case is based on the conjecture underlying the provision of collaborative doctoral programmes, maintaining that engagement of doctoral researchers with the "practice world" of the non-academic sectors will prepare them for pursuing career in those sectors. Using Pawson and Tilley's (*ibid*) vocabulary, the intervention (i.e. provision of collaborative doctoral programmes) is expected to provide 'resources' (i.e. access to industry environment and data) that influence the 'reasoning' of actors (i.e. professional practices chosen by doctoral researchers) and lead to the desired outcome (i.e. the perception of having acquired skills relevant for non-academic careers). Therefore, Pawson and Tilley's definition of programme (intervention) mechanisms consists of a combination of structure (the capacities derived from social resources) and agency (people's choices and reasoning). Accordingly, a collaborative doctoral programme is here understood as a mechanism combining the capacities of industry engagement (embodying generic skills) and individual specificities (embodying disciplinary skills). Hence, in brief the CMOcs framework can be applied in which;

- *Context* refers to country- and university-specific higher education system attributes in which industrial collaborative doctoral education programme is posited.
- *Mechanism* refers to industrial collaborative doctoral programmes providing opportunity for practical engagement of doctoral candidates.
- *Outcome* refers to the acquisition of transferable skills, as expressed by the subjects of the industrial collaborative doctoral programmes.

Then, the following research question is also put forward to be investigated qualitatively in this paper;

> *RQ3) What contextual mechanisms can explain the (in)effectiveness of collaborative doctoral programmes in equipping doctoral researchers with generic skills?*

Research paradigm and methodology

The research methods implemented in this paper serve a critical realist inquiry as the overarching research paradigm. Debating the empirical research methods in the field of education, Scott (2005) has argued that critical realism (CR) is the most appropriate meta-theory to underpin the methods. Critical realism per se, is a neutral research paradigm in terms of the

choice of research methods (Fletcher, 2017), and leaves that to be decided in accordance with the data needed to answer the research questions. Nevertheless, "[s]ince a particular object of research may well have different characteristics, it is likely that a mixed-method research strategy (i.e., a variety of methods in the same research study) will be necessary and CR supports this" (Mingers *et al*., 2013, p. 1). In line with this, CR scholars such as Fleetwood (2004) and Sayer (2004) consider critical realism as highly potent in bridging the interpretive and functionalist (hypothesis testing) paradigms in management studies. In other words, each of the quantitative and qualitative parts of research comply with a specific aspect within a critical realist research. Before introducing these aspects in the specific case of this research, a glimpse of the principles underpinning a critical realist research is presented briefly hereunder.

Six principles can be considered to be at the core of a critical realist research (Ryan, 2019). The first principle distinguishes between the intransitive and transitive objects of science. While the former refers to the objects of knowledge which exist regardless of human experimentation (e.g. the natural laws), the latter concerns those objects of knowledge which are shaped by human intervention (e.g. skills acquisition). The second principle distinguishes between three domains of reality, namely the real, the actual, and the empirical. Whereas the empirical domain refers to where the inquired objects of knowledge are observed, the domain of actual encompasses the events (part of which is empirically examined by researcher) emanating from the tendencies of the causal mechanisms originating from the domain of real - and often unobservable - structures. The third principle deals with the inferential logic, which in the case of critical realism is referred to as 'retroduction'. Based on this logic, the most likely explanation for the causal relation between the three domains of reality are inferred drawing on assessing the explanatory power of contending theories and conjectures about the structures underlying the emerging of events. That the preferred theory inferred from conducting a retroductive logic is considered only as the 'most likely explanation', implies at the fourth principle, which states that the truth is fallible, meaning that the observed causality might not necessarily apply to all the other possible contexts. Such a position resonates with the fifth principle, which adheres to modified objectivity, contending that not all the external influences on social objects can be removed, and this is due to the social systems being 'open systems', meaning that there exists human factors and contexts that are not feasible to control fully. Such a distinction of open systems from closed systems comprises the sixth principle.

These principles have significant implications for the interpretation of research results in a CR-based study. Jones (2011), for instance, explicates it that "[n]aive falsification – the testing of

a null hypothesis – is unsupportable in open systems as the absence of an effect may be due to some other process preventing it." (p. 206). Scott (2005) explains that "quantitative modelling comprises the adoption of certain forms of essentialism that misrepresent the emergent nature of the world" (p. 6). Scott mentions deterministic and reductionist essentialism, arguing that, specifically in the case of education research, the former (i.e. deterministic essentialism) eliminates human's agency, and the latter (i.e. reductionist essentialism) reduces the behaviour of many-sided objects of knowledge to just one side. Scott (*ibid*) points to the position taken by Pring (2000) that considers quantitative work as being applicable for determining the generalisability of objects and examining 'social structures which constrain' (Pring, 2000, p. 258) agents' activities; and qualitative work for determining agents' unique intentions and beliefs or their 'subjective meanings' (*ibid*).

In line with these arguments, a mixed-methods approach is adopted in this paper for conducting the data collection and analysis. There exist mixed-methods studies with rather similar research topics in the extant literature, for instance by Tuononen *et al*. (2019) who used mixed-methods, combining survey and interview data regarding academic competences and students' approaches to learning, and by De Grande *et al*. (2014) who combined survey data with data obtained through interviews regarding doctoral candidates' and industry employers' expectations about the skills needed for career transition of doctorate holders from academia to industry. The use of mixed-methods approaches in a CR-based research can also serve the purpose of data and method triangulation. Use of triangulation in a critical realist mixed-methods research is considered to be firmly supported by the abductive (retroductive) reasoning which is at the heart of CR-based research (cf. Modell, 2009). This is because it allows "deriving theoretically informed explanations while preserving researchers' sensitivity to variations in situated meanings" (Modell, *ibid*, p. 209).

As implied earlier concerning the implementation of quantitative methods, it is important to note that in general, realism rejects successionist modes of causal explanation, whereby one (the dependent variable) succeeds the other (the explanatory variable) (Scott, 2014). Furthermore, in his elaboration on rules for implementing quantitative methods under critical realism, Jones (2011) maintains that data analysis aims at identifying partial regularities as "relatively enduring, and potentially identifiable mechanisms … [that] must be seen as the beginning of causal explanation not as the end point" (p. 205). In complying with these principles, and considering the research questions put forward in the previous section, the research methods and respective data collection and analysis can be defined as follows. In order

to theorise about the 'real structures' that underlie the conduct of collaborative doctoral programmes, and consequently, the acquisition - or improvement - of generic skills by doctoral researchers, first, their experience from participating in collaborative doctoral programmes, and its contribution to the acquisition of skills, needs to be empirically surveyed. The results from a survey conducted in multiple contexts would be able to reveal a pattern of observations (outcomes), but not necessarily a law-like 'regularity' about them. As it is implied by Bhaskar's (1975) notion of *transfactual generalisation* – distinguishable from inductive generalisation - it is sought to come up with specification; under what circumstances the expected change from *causal tendencies* of underlying structures (or normic concepts) is more possible.

Consequently, the qualitative part of this research uses theory-driven interviewing in order to establish structure-experience linkages regarding doctoral researchers' perceived skills acquisition. Referring to the layered ontology of social reality in critical realism (see the second principle mentioned by Ryan), Smith and Elger (2014, p. 4) explain that "[…] interviews may not reveal real causes of action and present a partial picture. But it also means that without conducting investigations into action as experienced by actors, it is not possible to get insights into the actual and empirical representations of action". Furthermore, pointing to the social actions being context-situated in the CR accounts, Smith and Elger make it clear that interviews are used in the CR accounts for both interpreting the informants and analysing the "contexts, constraints and resources within which those informants act" (*ibid*, p. 6). As to the latter purpose, then, the interviews can be used in evaluating the adequacy of competing accounts about social reality, i.e. theories about the causal power of underlying structures. This approach is in fact underlined by Pawson and Tilley (1997) who, as prominent scholars of the CR research paradigm, had argued that interviews should be explicitly theory-driven, putting the interviewer in the expert position and giving the interviewee the role of confirming, falsifying, or rather refining that theory. Smith and Elger (*ibid*) explicate it that, based on Pawson's (1996) CMOcs, the expertise of researcher (interviewer) characterises wider contexts and outcomes of action, while the interviewee is mainly expected to highlight the explanatory mechanisms (see also the third principle mentioned by Ryan) that focus on reasoning and choices, and how these contribute to social change. Smith and Elger further imply that interviews form the basis for analysing the interplay of social contexts and generative mechanisms by providing insights into substantive events and experiences.

In this paper, doctoral candidates at two universities, one in Sweden and one in The Netherlands, are studied in terms of their expressed acquisition of transferable skills through

participation in *conventional* versus two different *industrial* collaborative doctoral programmes. In the Dutch university, the programmes on Professional Doctorate in Engineering (PDEng) provide doctoral candidates an opportunity to engage closely with firms during their doctorate programme and solve an engineering problem through their doctoral research. In the Swedish university, the Industrial PhD (also known as Organisational PhD) scheme gives doctoral candidates the possibility of being employed by a non-academic (mostly industrial) entity while completing their doctoral studies. In both cases, collaborative doctoral candidates' experiences are firstly compared to that their peers who are conducting a conventional doctorate programme at the same university. Data is collected by conducting a survey of doctoral researchers concerning their perceived improvement of generic skills, followed by in-depth interviews with a group of respondents to the survey in order to gain more detailed accounts of the "mechanisms" affecting their generic skills acquisition as the "outcome". As Harrits (2011) explicates, the role of qualitative methods in a CR-based mixed-methods research is closer to uncovering of mechanisms, as the patterns and regularities revealed by the quantitative methods might not necessarily reflect the mechanisms at work (see the fourth, fifth and sixth principle mentioned by Ryan).

Accordingly, in this study the survey questions mainly concerned the context and outcome of participation by the doctoral researchers in the doctoral programmes, include the departmental affiliation of the respondents and the type of their doctoral programme, whether doctoral studies of respondent includes collaboration with public and private entities or not, the temporal length of such collaborations, whether or not the collaborating entity partially or fully funds the doctoral project, and whether or not the collaboration has helped the deepening of the discipline-specific knowledge and the acquisition of the generic skills.

The interviews in a CR-based research are 'theory-driven', which as Hamilton-Smith and Hopkins (1998) explicate it, differs from both 'structured' and 'unstructured' interviewing methods, and the interviewees' role is considered to be confirming, falsifying or refining the theory that the interviewer uses (Pawson, 1995). The implication for the interview is that data are constructed around a theory, and not just collected (which is the case in structured interviews) or interpreted post-hoc (which is the case in unstructured interviews) (Hamilton-Smith and Hopkins, *ibid*). Accordingly, in this study the questions of the interviews aimed at retroductive uncovering of the mechanisms underlying the occurrence of collaborations, and thereby, abductively establishing the structure-experience configurations around the issue of learning the generic skills. More specifically, the interview protocol which was developed for

conducting the interviews at the two universities, included sections dedicated to discussing, in further detail than the survey, the context of their collaborative doctoral programme, including the type of industry they are engaged with and the background of collaboration, the mechanism of the collaboration, including the funding and the engagement format and intensity, and the outcome as perceived by doctoral candidates with special focus on the acquired generic skills.

Data

Quantitative data

Given the above-mentioned foundations about the methodology, with regards to the first research question, the survey questionnaire included questions on the existence of collaboration with non-academic (public or private) entities during doctoral education, and whether such collaborations have helped in the candidates' perceived acquisition of generic skills as well as deepening of discipline-specific knowledge. With regards to the second research question, which concerns the intensity of doctoral candidates' relationship with firms, surveyees were asked about 1) the duration of their research collaboration, and 2) whether the collaborating entity partially (or fully) funded the candidates' research project. Table 1 shows the factors enquired on in the survey questionnaire corresponding to the above-mentioned elements.

Table 1 – The survey questions addressing the variables of the quantitative analysis

Survey question addressing the research variables	**Variable name**	**Options for answer**
In your assessment, has the collaboration with the collaborating firm / organisation deepened your knowledge in your academic specialisation area?	knwl	- Yes, to a large extent - Yes, somewhat - No
How long will your collaboration with the non-academic partner last during the whole PhD education period?	colldur	- Less than or equal to six months - More than six months
Does the collaborating firm / organisation partially / fully fund the doctoral project?	cofnd	- Yes - No
In your assessment, has the collaboration with the collaborating firm / organisation helped you acquire at least one of the transferable skills*?	skill	- Yes, considerably - Yes, a little - No

* The list of transferable skills (shown in Table 2) was given under the survey question.

The results from the surveyees answers to the above-mentioned questions were transferred to Stata software, where categorical variables were defined in relation to all these questions. Multiple logistic regression was then applied to investigate whether a pattern (demi-regularity, but not necessarily a correlation) can be found between the explanatory variables of disciplinary

knowledge, collaboration duration, and funding, and the explanant variable, i.e. generic skills acquisition. The online survey questionnaire was distributed in the spring of 2019 to a total of 2491 respondents from the two universities (1219 from the Swedish and 1272 from the Dutch university), returning a total of 204 responses (140 and 64 responses, respectively), measuring to an overall 8.2% response rate. Out of these 204 respondents, 105 indicated that their doctoral education includes collaboration with a non-academic entity. Then, out of these 105 respondents, 6 had not started their collaboration with the non-academic entity at the time of the survey, leaving 99 respondents (53 from the Swedish university and 46 from the Dutch university) as having already engaged with the non-academic entity. Therefore, the data analysis applies to these 99 observations for assessing doctoral candidates' perceptions regarding the skills.

Qualitative data

While the qualitative data collection also included questions in close connection to the above-mentioned three explanatory variables on the doctoral candidates' research collaborations, it aimed to further explore for revelatory evidence on the 'underlying mechanisms' with potential for generating the 'actual event' of collaborations, and consequently, influencing the 'experienced outcome' in terms of generic skills acquisition. In complying with their critical realism approach, Pawson & Tilley (1997) have recommended interview respondent selection to be based on their 'CMO investigation potential'. Accordingly, the realist sampling of interviewees is designed to test the contexts that are hypothesised to matter (Manzano, 2016).

Accordingly, with the aim of answering the third research question, the interview questionnaire included questions on the employment status of the candidates in connection with the financing of the doctoral project, the candidates' academic departmental affiliation and the role of supervisors in connection with the candidates' field-specific knowledge gain from the collaborations, the frequency and the mode of attending the premises of the firms or collaborating non-academic entity in connection with the duration of collaboration, and the types of generic skills acquired in connection with the question on whether and how the candidates' intersectoral collaboration has contributed to the acquisition of those skills. Furthermore, the respondents were asked to reflect on a question concerning which of those skills are considered to be specifically important for the next career step by the candidates. In order to distinguish more clearly between the "semi-industrial" and "industrial" doctorates, the interviewees at each university included respondents from both those who are conducting a conventional doctorate programme but are considered "external candidates", and those who are

conducting Industrial PhD (in Sweden) or Professional Doctorate in Engineering (in The Netherlands). As the interviewees are supposed in the CR-based theory-driven interviews to be informed about the investigated theory or conjecture, they were already asked in the survey about the type of generic skills they consider as being improved through their collaborative programme. These skills were selected based on the author's own adoption from the review made by Matas (2012) on doctoral skills development around the world, and categorised according to the aforementioned grouping of the generic skills by González and Wagenaar (2003) in three groups. The resulting categories and types of generic skills, which was used in the survey of doctoral researchers, is shown in Table 2.

Table 2 – Types of generic skills the survey and interview subjects were asked about.

Types of generic skills asked about in terms of acquisition through the intersectoral research collaboration	**Generic skill category**
Communication and presentation skills Team working skills Networking skills Self-management and work ethics	Interpersonal skills
Managing data and information technology Analysis and problem-solving Research skills	Instrumental skills
Project management skills Leadership and supervision skills	Systemic skills

It is noteworthy that in critical realism, data obtained in open systems are seen as 'ficts' (Olsen and Morgan, 2005) meaning that they may not be true mirror-like representations of reality, but are still useful for warranted arguments in terms of speculation and as sources for explanation. (Jones, 2011, p. 208). Accordingly, although the interview subjects' expression of experiences in having acquired specific skills can be seen as being 'subjective' judgement, but are considered as reflections by an 'agent' who is reflecting some reality about how her reasoning (experience) has been influenced by being exposed to the specific resources provided by the respective 'structure'.

Discussing the issue of sample in in-depth interviews in a research which has realism as its epistemological foundation, Crouch and McKenzie (2006, p. 11) point out that "[r]ather than being systematically selected instances of specific categories of attitudes and responses, here respondents embody and represent meaningful experience–structure links". Based on this

argument, the authors contend that in such a research, "[…] the issue of sample size – as well as representativeness - has little bearing on the project's basic logic" (Crouch and McKenzie, *ibid*, p. 1). Accordingly, the in-depth interviews in this study were conducted with 38 doctoral candidates at the two universities, with 19 interviewees belonging to each university. In case of the Swedish university interviewees, 7 of them were Industrial (Organisational) PhD candidates, while the other 12 were conventional PhD candidates. In case of the Dutch university, 8 of the interviewees were PDEng candidates, while the other 11 were conventional doctoral candidates. Overall, the interviews lasted from 22 to 51 minutes, with 31 of them conducted face-to-face, and the remaining seven conducted virtually (over Skype or phone). All of the interviews were voice-recorded (with the consent of the interviewees) and transcribed before using them in the analysis. Since the interviews were theory-driven, the analysis used directly interviewees answers to the questions to confirm or falsify the conjectures underlying the three research questions.

Findings

1) Findings from the survey

As mentioned in the methodology section of this paper, since all the variables used in the analysis of survey data are categorical variables, multiple logistic regression was implemented to assess the associability of defined explanatory variables with the explanant.

Table 3 – Results of multiple regression analysis of the survey data.

skill	Coef.	Std. Err.	z	P> | z |	[95% Conf. Interval]	
No	(base outcome)					
Yes, a little						
colldur						
More than 6 months	1.07	0.85	1.26	0.207	-0.59	2.73
cofnd						
Yes	-0.19	0.82	-0.23	0.820	-1.78	1.41
knwl						
Yes, somewhat	1.42	0.80	1.76	0.078	-0.16	3.00
Yes, to a large extent	1.93	1.24	1.55	0.120	-0.50	4.35
cons.	-0.54	0.87	-0.62	0.538	-2.25	1.17
Yes, considerably						
colldur						
More than 6 months	1.56	0.96	1.61	0.107	-0.33	3.44
cofnd						
Yes	0.68	0.84	0.81	0.419	-0.96	2.32
knwl						
Yes, somewhat	2.05	0.93	2.20	0.028*	0.22	3.87
Yes, to a large extent	3.79	1.29	2.93	0.003**	1.25	6.32
cons.	-2.14	1.08	-1.99	0.047	-4.25	-0.03

The outcome variable (explanant) is the skills acquisition, for which three levels has been defined: no improvement experienced, a little improvement experienced, and considerable improvement experienced. Table 3 demonstrates the results gained from the multiple regression analysis run on Stata software using the *mlogit* command. The dependent variable (skill) and the independent variables (colldur, cofnd, and knwl) were explained in the Table 1. As seen in the results table, the 'no improvement' outcome has been chosen as the base outcome, with which the results from other two categories of outcome are compared. The results from the multinomial regression demonstrates that, perhaps surprisingly, the intensity of relations with collaborating firms does not show a significant association with the improvement of generic skills acquired by the doctoral researchers. This can be seen in the regression results where the p-values associated with the explanatory variables for both categories of "a little improvement" of generic skills and their "considerable improvement" are larger than 0.05. On the other hand, the results demonstrate that there exist a pattern of regularity in the form of harmonious development between doctoral researchers' perceived improvement in discipline-specific knowledge and their generic skills acquisition. This can be seen in the regression results where the p-values associated with the explanatory variable of disciplinary knowledge (variable *knwl*) for the case of considerable improvement of generic skills are smaller than 0.05, and this for both the situations of "somewhat" and "to a large extent" deepening of discipline specific skills. Furthermore, the positive sign of the respective coefficients (2.05 and 3.79) implies that the association between the concerned two variables is in the form of in-tandem development (positive correlation), compared with the base outcome where no improvement in generic skills are experienced. It is however noteworthy that such an observation is not made about the relation between discipline-specific knowledge improvement (at any scale) and "a little" improvement of generic skills through the intersectoral collaborations. In other words, the experience of substantial improvement in generic skills is gained only when a noticeable discipline-specific knowledge gain is also made. Nevertheless, as mentioned earlier, within the CR paradigm these observations are not considered as sufficient in explaining the *causality,* and qualitative inquiry has the main role in uncovering the context-specific actualisation of underlying mechanisms' *tendencies,* i.e. their contingent actualisation.

2) Findings from the interviews

As indicated earlier, the goal of conducting interviews has been to dig into the underlying structures capable of explaining the relation between contexts (doctoral education policies), mechanisms (collaborative doctoral programmes), and outcome (doctoral researchers'

expressed experience about their skills acquisition). The forms of funding of doctoral research projects are determined based on the type of doctoral programme recognized by the university, which in turn are defined in accordance with the national and institutional requirements. Therefore, the candidates' (collaborative) doctoral programme is a context-specific mechanism, the potential of which are actualised conditional to other contextual mechanisms interactions and influences. The final aim of interviews is to enable us to theorise about such mechanisms.

Findings from the interviews at the Dutch university

A) Conventional doctorate researchers

- Funding as a context-based mechanism

While the employment status of the PhD researchers interviewed is not identical, a large majority are not employed by the university, but by a private or public entity in the Netherlands, and even in few cases, abroad. Not only in these cases, but also in the cases that the PhD candidate is employed by the university itself, the funding for the doctoral studies of the candidate is often secured through external resources, mainly by a non-academic entity, which in turn in some cases are receiving a research grant from European or national research funding instruments. Doing the PhD studies in a part-time or external PhD mode is hence prevalent among the interviewed candidates, as they spend part, or in some cases almost the entire period of their PhD studies at the site of their non-academic employer. It is also notable that the funding mechanism for a single PhD candidate can change during the course of PhD studies, as the initial secured finances might not be sufficient for the whole period of PhD.

- Engagement format and the perceived skills acquisition as outcome

With regard to PhD researchers' intersectoral engagement format and intensity, a distinction can be made between those employed by the university, and those employed by a non-academic entity. For those employed by the university, spending time at the sites of non-academic research collaborators is much less prevalent, even though the PhD project is still usually funded by a non-academic partner. The interviewees conducting their PhD with such arrangements expressed the interpersonal types of generic skills - such as communication, team-working, networking, and self-management - as being improved through their intersectoral interactions. An interviewee made a further distinction with regard to the types of interpersonal skills gained via collaboration with different types of non-academic entities, indicating that collaboration with firms helps improving team-working skills more, since "they are also technically skilled people", while collaboration with public service entity helps to improve

communication skills, as the individuals working there have a different set of skills and knowledge, which challenges researcher's conveying abilities.

For those PhD researchers employed by a non-academic entity, the share of doctorate time spent at employer's - or other non-academic research partner's – sites is considerably higher than those employed by the university, ranging from 40 to 80 percent of the available time. This group of PhD researchers pointed to a more inclusive range of generic skills being improved through their intersectoral engagement. In addition to interpersonal skills, it is not rare among them to mention instrumental skills – such as data management and research skills – and systemic skills – such as project management.

B) Professional Doctorate in Engineering (PDEng)

For completing a PDEng education, the students need to gain 130 credits, out of which 52 credits is related to the educational part, and the rest is related to the project work. That educational part includes, based on the student's choice, between six to ten credits on courses related to 'professional skills'. The Graduate School of the university provides those professional development courses. For any PDEng project all the funding is externally secured upfront, usually by a company which gets a PDEng student to work on the project. Hence, the company has a large influence on the content of the project.

- Funding as a context-based mechanism

The funding for PDEng studies are externally secured, meaning that the projects that PDEng candidates need to work on are always financed by an entity outside the university. The forms of external funding mentioned by the PDEng interviewees regarding the financing of their doctoral research projects are but diverse, and include; fully financed by a company, co-funded by two different companies, co-funded half by a company and half by a European grant, funded by a group representing a network of companies in an industry, funded by a ministry, co-funded by the government and a consortium of companies, or funding from a European project involving several universities, research institutes and industry.

- Engagement format and the perceived skills acquisition as outcome

Even though the PDEng candidates interviewed are all working to solve a concrete technological problem that the firm or organisation funding their PDEng project is dealing with, most of their PDEng studies' time is spent at the university campus. While for most of them, the two years of their professional doctorate studies can be divided to two one-year periods, distinctly dedicated to course work and project work, for some of them such a temporal

distinction cannot be made, as they need to progress on the course work and project work in parallel. It is recognisable from the points made about the skills development by the interviewees that, while an improvement in interpersonal skills is mentioned by almost all of them, it is chiefly the group leading their course work and project work in parallel that also mention systemic skills, specifically project management skills.

Findings from the interviews at the Swedish university

A) Conventional doctorate researchers

- Funding as a context-based mechanism

The interviewed PhD researchers conducting a conventional PhD programme are all employed by the university, but some of them are at the same time employed by another public or private entity, which has permitted them to spend part of their time on the PhD education. The funding for their PhD project, however, is usually secured through European or national research funding instruments or firms and foundations. Combining two, or sometimes more of these funding mechanisms for financing a single PhD project also seems not to be rare. Even in cases that the PhD candidate is solely employed by the university, interaction with a public or private entity for the purposes of data collection is common. At the same time, the lack of formality in such interactions, and absence of a designated contact person at the side of the non-academic entities with whom the PhD researchers engage, as the interviewees explain, reduces the efficiency of collaborations.

- Engagement format and the perceived skills acquisition as outcome

Concerning the experience with generic skills enhancement throughout the course of doctoral education, a distinction can be made between the respondents conducting conventional PhD studies without being part of a large research consortium, and those who are part of one. Those who are not part of a large research consortium, are often interacting with non-academic entities in a very informal way, and if they mention an experience of improved generic skills, it usually includes only the interpersonal skills, such as communication, networking and teamwork. On the other hand, for those who are part of a large research consortium, such as the ones funded by the European Commission, the expression of skills improvement often includes some of the instrumental and systemic skills as well, such as data management and project management skills.

B) Industrial PhD (Organizational PhD)

- Funding as a context-based mechanism

In Sweden, industrial doctoral students are employed by a company or an organisation, and concomitantly pursue doctoral studies at a university, where they spend at least half of their doctoral studies' time during the working year. An industrial doctoral student normally receives the whole of PhD salary from the company or organisation employing her. While this was the case among the interviewed industrial doctoral researchers, the forms of funding mentioned by the them regarding the financing of their doctoral research projects were not identical. These forms include projects co-funded 50% by companies and 50% by a private foundation, fully funded by a private foundation related to a company, fully funded by a private company, or co-funded by a research partnership programme between industry and a state agency.

- Engagement format and the perceived skills acquisition as outcome

While most of the interviewees doing an industrial doctorate are spending most - or almost all - of their PhD time at the premises of companies or organisations employing them, fewer of them have an opposite arrangement, visiting the company on a weekly basis or less. Nevertheless, interpersonal skills as well as instrumental skills are mentioned by almost all of the interviewees as being improved during their doctoral term. As to the interpersonal skills, the interviewees perceive them to be enhanced mainly due to their need to communicate with individuals in an industrial working environment with a variety of backgrounds, which for them means interacting with different mind-sets. As to the instrumental skills such as data management and problem-solving, the fact that they need to address a concrete technical challenge their employer is dealing with, is indicated as the explication. Nevertheless, there is hardly a mention of improvement in systemic skills.

Discussion

Under a critical realist research framework, conducting an argument based on data obtained from the ontological layer of 'empirical' aims to explain context-laden 'actualisation' of causal tendencies of mechanisms, which in turn emanate from 'real' structures whose causal powers are explained by theories. Accordingly, the ultimate goal of data analysis is to refine an existing theory about the causality of social objects and structures (Elder-Vass, 2010). The inferential mode implemented under the CR paradigm for this purpose includes *abduction* and *retroduction* (Danermark *et al*., 1997). Whilst around the turn of the 19th century Peirce (1898) introduced these two terms as equivalent, and as a logical form of inference distinct from induction and deduction, more recent accounts consider the two to be different. For instance,

Olsen and Gjerding (2018) explain that abduction is run by the analogical discovery of similar cases in order to achieve a novel categorization of the subjects. More explicitly, they posit that;

> CR defines abduction as a process where an empirical phenomena or event is *re-contextualized*, usually by a transport of the phenomena from one set of concepts into another. Danemark et al. (2002) posits that abduction (as re-contextualization) should be distinguished from *retroduction*, such that abduction opens up new ideas vis-a-vis the studied phenomena, and retroduction infers the causal processes constituting alternative general mechanisms explaining the phenomena. The crux of retroduction is to imagine a model of a generative mechanism, which insofar as it exists would explain the re-contextualized phenomena (Bhaskar 2008).

Accordingly, elucidation of the findings from the data analysis in this paper need to comply with the logic of abductive and retroductive inference. The findings from the quantitative analysis in this paper proposes that, doctoral candidates' experience of having gained generic skills through intersectoral collaboration, is associated with their experience of having gained a significantly (considerably) deepened discipline-related knowledge through the collaboration, rather than with the intensity of the collaboration manifested by its duration or funding composition. Within a critical realist research, however, we cannot necessarily infer from this observation that acquisition of knowledge in the disciplinary area *causes* the acquisition of generic skills. This is due to CR's rejection of correlation-based understanding of causality, and its insistence on mechanism-based *explanation* (rather than providing laws for *prediction*). Furthermore, the absence of manifestation of the effects of a potential causal power at the actual events level - and consequently its outcome at the empirical level – does not necessarily imply the impotence of underlying real mechanisms, since a counter-affecting mechanism might have inhibited that potential mechanism from actualisation of its causality. Therefore, in order to further investigate the causal power of the hypothesized mechanisms, deeper insights from the qualitative inquiry are sought. As Bhaskar points out, the social systems are 'open systems', for which quantitative methods can help to identify some patterns or partial regularities - what Lawson (1997) refers to them as *demi-regularities* or *demi-regs*. The primary role of these demi-regularities is "to direct social scientific investigations, through providing evidence that, and where, certain relatively enduring, and potentially identifiable mechanisms have been in play" (Lawson 1997, p. 207).

Accordingly, the result of the quantitative analysis in this study implies that in conducting the retroductive identification of mechanisms through the qualitative inquiry, attention is needed to *structures* with potential to codetermine the collaboration-related experiences of *agents* (i.e. doctoral candidates) through disciplinary factors. Therefore, comparing the expressed

experiences of doctoral researchers participating in conventional 'semi-industrial' versus collaborative 'industrial' doctorate programmes is viable. The doctoral programmes are embedded in the context of each university and country, and as an intervention mechanism, aim to equip the programme participants with certain skills. Then, in CR terms, their comparison can help in identification of what Lawson termed *contrastive demi-regularities,* which as he explains, provide the basis in creating the causal explanations. These contrastive demi-regularities help to learn where or when a mechanism is not working, and may give clues to new mechanisms (Jones, 2011). In other words, between two similar states of affairs that tend to generate similar outcomes, "[t]he existence of contrastive demi-regularities provide *prima facie* evidence that there is an unidentified causal mechanism(s) at work, whose influence accounts for the unexpected contrast between two outcomes under investigation." (Fleetwood and Hesketh, 2010).

The above-mentioned logic is also compatible with conducting comparative case studies, which according to Danermark *et al*. (1997) is one of the five strategies usable to accomplish the retroductive inference[2]. To do this, Pawson and Tilley's (1997) CR-based Context-Mechanism-Outcome configurations (CMOcs) provide a tool, well corresponding to the identification of contrastive demi-regularities. Here, the CMOcs drawing on a same higher education system context at each university, provide possibility for the comparison of "industrial" collaborative doctorates with conventional doctorates (which include "semi-industrial" collaborations in the form of external PhD). The industrial collaborative programmes, then, represent mechanisms that are conjectured to improve the generic skills of their participants, i.e. doctoral candidates by providing them access to new resources, i.e. industrial environment and data.

In the first context, the experiences expressed by the PhD and PDEng candidates from the Dutch university imply that when the learning of theoretical and practical dimensions take place in parallel, the candidates' experience of improvement in generic skills becomes more comprehensive. This was recognisable from the observation that those PDEng candidates who were conducting their course work and project work in parallel, and those PhD candidates who were dividing their PhD time between university campus and a non-academic workplace, mentioned acquisition of interpersonal, instrumental as well as systemic skills distinctively more than their peers in the respective opposite groups. Both of these experience differences imply to a demi-regularity, pointing to the positive impact of the 'co-development' of

[2] The other four strategies they propose include counterfactual thinking, social and thought experiments, studies of pathological cases, and studying of extreme cases.

theoretical and practice-based learning on the participants' perception about their acquired generic skills.

In the second context, the observations from the sample of conventional and Industrial doctorates at the Swedish university demonstrates that the candidates' perception about acquiring generic skills is specifically associated with the level of formality of engagement with industry. This might be explained by the efficiency of access to research data, which according to the interviewees, is higher in the cases of more formal relation between the firm and doctoral researchers. This can obviously be due to the fact that access to data significantly influences the process of data management, project management and problem-solving. Nevertheless, the absence of systemic skills improvement in the experiences of Industrial PhD candidates, in spite of acquiring interpersonal and instrumental skills, can imply that the formality of the relation is not the only issue at stake, and the scarcity of contact with the academic environment, which is usually the case with Industrial doctoral candidates, negatively influences the integration of interpersonal and instrumental skills.

Having established CMOcs for each case, the abductive inference requires to compare those CMOcs from different contexts and thereby infer an approved or a modified theory concerning the skills acquisition through collaborative PhD. As Olsen and Gjerding (2018, p. 14) put it, "the function that abduction plays in CR must rest on the assumption that the researcher generates hypothesis by the identification of something similar across contexts". What the comparison of the two cases of CMOcs indicate is that, what keeps the collaborative doctoral programmes from effective and comprehensive improvement of doctoral researchers' generic skills, is much more likely related to deficiencies in the co-development of disciplinary and generic skills. As the results from the Swedish case demonstrate, these two skills need not only to develop in parallel, but also with a 'balanced' share of time dedicated to each.

Earlier, De Grande *et al*. (2014) had shown that, in Flanders, a disparity could be found between the industrial employers and doctoral candidates in terms of the perceptions on necessary skills, as "[…] transferable competencies such as project management and business skills are underestimated by doctoral candidates." The findings in this paper, however, can shift the blame with regards to the underestimation of the importance of these skills to deficient design of doctoral programmes; more so in case of collaborative programmes. As Smith and Elger (2014, p. 5) put it regarding the causal power of social realities, "in actual events in time, agents are responding to pressures and forces in context-dependent ways, but also in ways which unite them (or make their actions intelligible) as agents". Accordingly, doctoral candidates respond

to the learning opportunities (and make respective choices) in harmony with prevalent practices on doctoral education, but also in tandem with the specific conditions in their doctoral programme. Hence, the design of collaborative doctoral programmes, no matter which country- or higher education system specific type, can be tailored to accommodate the parallel and intertwined development of disciplinary and generic skills, given their common and ubiquitous underlying cognitive structures. An example of structural elements common to all types of collaborative programmes is the issue of relation with industrial supervisors. Aprile and Knight (2019) studied the impact of work integrated learning placements on students' professional readiness, and found that relationship with workplace supervisors is one of the main contextual features of placement sites influencing students' perceptions of career readiness. This was in fact an aspect of collaborations that was also raised by a number of interviewees, mainly referred to with regards to the level of formality of the relation and transparency of expectations. In critical realist terms, such underlying structures common to all contexts are referred to as *transfactual* causal structures, which do have normic implications as they refer to necessary conditions, but their consequences are contingent to the contextual conditions[3]. A retroductive thought operation based on the above-mentioned result would perhaps imply that, in order to meet the goal of integrated design of doctoral skills development programme, a pedagogical form of collaboration between academe and industry is required in defining the intertwined development of disciplinary and generic skills during collaborative doctoral programmes. In other words, one transfactual condition undermining the generic skills development seem to be related to the non-involvement of industry in the design of industrial doctoral studies curricula, resulting in misalignment of disciplinary and generic skills development during the course of doctoral education. The case of PDEng programme, for the content of which the professional society of Dutch Royal Institute of Engineers (KIVI) have more influence, indicates that such a collaboration meaningfully increases the efficiency of collaborative doctoral programmes as an intervention mechanism.

Conclusion

This paper aimed at providing an explanation on whether and how industrial collaborative doctoral programmes facilitate the acquiring of generic skills by doctoral researchers. For this purpose, and relying on a critical realist research paradigm, a mixed-method study of current participants in two industrial collaborative versus conventional doctoral programmes was

[3] This approach to generalisation in critical realism is contrasted with inductive statistical extrapolation in empiricist accounts which implies outright predictions (cf. Danermark, 1997).

conducted. In both of the Dutch and Swedish cases, firstly the experience of doctoral candidates from collaborative programmes were compared to those of participants from conventional doctoral programmes in terms of their perceived acquisition of skills during the doctoral education. The results from a CR-based analysis of the data collected from a questionnaire-based survey and theory-driven interviews showed that, despite some prior findings or conjectures in the literature, the intensity of relation with industry per se cannot readily explain the success of collaborative programmes in improving generic skills of doctoral candidates. More specifically, the current study did not find funding composition of the collaborative programmes – whether the industrial partner co-funds the doctoral research project or not - to be associable with the skills acquisition experience. This finding resonates indirectly with Auranen and Nieminen (2010) who conducted an international comparison of the impact of universities research funding's competitiveness on their publication efficiency, and found no straightforward connection between the two. Similarly, the duration of collaboration did not prove in our study to be per se associable with the skills acquisition experience. Rather, the conceived results suggest that a full-fledged acquisition of generic skills has to do with their harmonious development with disciplinary theoretical skills. Expressed in more details, the kinds of generic skills which have less to do with disciplinary competencies (such as interpersonal skills), would combine effectively with instrumental skills (such as research skills and data management), and lead to the development of systemic skills (such as project management), when the theoretical and practical aspects of PhD training develop hand in hand and in equilibrium. In this sense, the findings in this paper are in agreement with those of Barnacle and Dall'Alba (2011) and Mowbray and Halse (2010) who called for intertwining of the development of different categories of skills. Nevertheless, this study takes a step further, and advocates for 'parallel' and 'balanced' development of generic and disciplinary skills.

An implication of these findings is that, as Cryer (1998) had also suggested, the main initiative concerning transferable skills development would best be designed and implemented at departmental level, rather than university level. Based on the findings in this paper, discipline-specific skills have significant interrelation and influence on the identification and development of generic (transferable) skills. Hence, the findings in this study challenges the provision of academic courses on generic skills by university-wide entities such as unitary doctoral graduate schools at the university level, as such entities would hardly be able to harmonise the contents of generic skills development courses with discipline-specific knowledge and skills development. Furthermore, the findings of this study point to the necessity of closer

engagement of industrial partners of collaborative doctoral programmes in designing the process of skills development for industrial collaborative doctoral candidates. This is due to the observation that generic skills development needs to be paralleled and balanced with academic skills development in order to deliver the optimal results for the graduates, and hence, for the industry eventually employing them.

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