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Doctoral graduates' transition to industry: networks as a mechanism? Cases from Norway, Sweden and the UK

Eloïse Germain-Alamartine ^a, Rhoda Ahoba-Sam ^b, Saeed Moghadam-Saman ^c and Gerwin Evers ^d

^aHelix Competence Centre & PIE, Linköping University, Linköping, Sweden; ^bLincoln International Business School, University of Lincoln, Lincoln, UK; ^cUIS Business School, Centre for Innovation Research, University of Stavanger, Stavanger, Norway; ^dDepartment of Business and Management, IKE Research Group, Aalborg University, Aalborg, Denmark

ABSTRACT

Increased public investment in PhD education to drive innovation has led to a recent rapid growth in the number of PhD graduates. Academic labour markets have not developed at the same pace. An ever-larger share of the graduates is finding employment in industry. The transition from academia to industry is not always easy. The present study aims to provide insights into the role played by PhDs' networks in the job search after graduation. Our data comprise interviews with industry-employed doctoral graduates in STEM disciplines from Sweden, Norway and the UK. Our findings show that PhDs' autonomously built personal networks can help match their specific scientific expertise with labour market demands. We distinguish country-specific patterns and characteristics of the transition, in which regional career paths are more (Scandinavia) or less (the UK) noticeable. The study has practical implications, in particular for PhD students and graduates, related to their career orientation.

KEYWORDS

Doctorate holders; PhD graduates; doctoral education; university–industry networks; non-academic career; overlapping internal labour markets

Introduction

In the last few decades, the number of PhD students annually trained by universities in OECD countries has increased markedly (OECD 2016). This increase is, however, in strong contrast with the little growth in the number of available academic positions for which these graduates are traditionally trained (OECD 2016; Larson, Ghaffarzadegan, and Xue 2014). Consequently, more and more doctoral graduates are searching for jobs outside academia (Bloch, Graversen, and Pedersen 2015). Although unemployment among this group is lower than in the general population (Auriol 2010), an increasing share end up in positions for which they are overqualified or which are outside their specific field of expertise (National Science Foundation 2012).

The latter developments are often explained by the very specific scientific expertise developed during PhD training, which makes it difficult for graduates to find a job matching their education and skills outside academia (Maki and Borkowski 2006). In response, many scholars and policymakers have argued that more attention should be given to the development of generic skills in doctoral schools (Thune et al. 2012; Vitae 2010; LERU 2016). This could potentially begin to close the gap between the skills of PhDs and industry demand – although solely relying on this can limit the

CONTACT Eloïse Germain-Alamartine  eloise.germain@liu.se  Helix Competence Centre & PIE, Linköping University, 581 83 Linköping, Sweden

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added value of doctoral education over Master's education (Brennan 1998; Hager, Holland, and Beckett 2002; De la Harpe, Radloff, and Wyber 2000). Hence, different mechanisms may be used for finding suitable jobs outside academia to complement these kinds of initiatives.

Adding to research on the gap between skills and PhDs' employability, we argue that an in-depth understanding of the current processes by which PhD graduates obtain employment in industry is necessary. Existing knowledge is mostly focused on the destination of doctoral graduates (Auriol 2007; Drejer, Holm, and Østergaard 2016), with little insight into the actual transition process (Manathunga, Pitt, and Critchley 2009; Cruz-Castro and Sanz-Menéndez 2005). Granovetter's (1974) work demonstrated the importance of networks as enablers of labour market matching processes by reducing the search costs and uncertainty involved. We therefore posit that network connections with industry actors may fulfil a similar important role in PhDs' job searches, especially since more and more PhD studies transcend academic and industrial settings (Wallgren and Dahlgren 2007; Thune 2009), offering opportunities to develop these ties (Lam 2007). Additionally, there is some research suggesting that PhDs in some cases could benefit from their supervisors' networks (Bøgelund 2015).

While university–industry connections undoubtedly play a role in the labour market matching process, there is little research on the importance of these networks for doctoral graduates entering industry. The increasing trend of doctoral graduates moving to industry, either by preference or owing to external factors such as labour market conditions, asks for a deeper understanding of the university-to-industry transition process. Hence, this study aims to explore *the transition of PhD graduates to industry*, looking more specifically at how university–industry networks, as well as the regional and national contexts, explain such transition.

In the qualitative research approach adopted, 31 interviews were conducted and analysed. In order to ensure both diversity and comparability, the interviewees were STEM doctorates working in industry who had graduated from universities in Sweden, Norway or the UK situated either in the central or a peripheral region. The findings show that networks play an important role in increasing the quality of non-academic employment after graduation, by matching PhDs' specific scientific expertise with labour market demand – but these networks are built by the PhDs themselves, with little support from their supervisors. Additionally, there are country-specific patterns and characteristics of university–industry transitions. These findings thus contribute to the literature on university–industry networks as well as the literature on the employment of highly educated workers.

Literature review

Challenges with employment opportunities for doctoral graduates

With the democratization of higher education in the past century, there has been an increasing supply of highly educated workers on the labour market (Auriol, Misu, and Freeman 2013; OECD 2016). This phenomenon goes along with the shift towards a knowledge-based economy in the European Union and consequently increasing demand for such knowledgeable individuals (Lisbon European Council 2000). While the annual growth in absolute numbers of graduates is largest at undergraduate level, the relative growth is largest among PhDs (OECD 2016).

Doctoral graduates are traditionally educated to conduct research in the area in which they have become experts and to teach in higher education institutions (Group of Eight 2013). However, although an increasing number of university students has created a greater demand for doctoral graduates in the academic labour market, the growth in the availability of such graduates seems to have exceeded the demand. This imbalance in demand and supply has led to a bottleneck in the academic career progression of PhD holders (Andalib, Ghaffarzadegan, and Larson 2018; Etmanski, Walters, and Zarifa 2017; Larson, Ghaffarzadegan, and Xue 2014; Neumann and Tan 2011).

Increasingly, therefore, doctoral graduates are leaving academia to work in industry (Bloch, Gravesen, and Pedersen 2015; Herrera and Nieto 2013). Being highly educated, it might be assumed that they have privileged access to the industrial labour market in knowledge-based economies. However, there are many mismatches on this market (Cedefop 2016; Gaeta, Lubrano Lavadera, and Pastore

2016; Allen and van der Velden 2001): skills mismatches, field-of-study mismatches and over-education or qualification mismatches (Corcoran and Faggian 2017), of which the latter has received the most attention in the literature (Green and McIntosh 2007; McGuinness and Byrne 2015; McGowan and Andrews 2015).

Employment mismatches need to be addressed because they entail a sub-optimal use of human capital, leading to a decrease in productivity (McGowan and Andrews 2015, 2017). This further suggests that the problems doctoral graduates face on the industrial labour market is not purely quantitative as is the case with the oversupply of PhDs on the academic labour market, but more about realizing a suitable match between their qualifications and the jobs on offer. These challenges therefore call for a closer look at what actually occurs at the university–industry interface.

University–industry networks and labour markets

The career trajectories of doctoral graduates have been the subject of many studies (Mangematin 2000; Cañibano et al. 2018), including in their scope both internal factors, such as personal preferences, characteristics of the study and network opportunities (Mangematin 2000; Jackson and Michelson 2015) and external factors, such as labour market demand (Bloch, Graversen, and Pedersen 2015). However, the actual means used by doctorate holders to find a job outside academia have received little attention.

Granovetter (1974) pointed to networks as the most important means for facilitating labour market matching. Networks facilitate awareness of the available employment opportunities, as well as providing actors with more information on these opportunities, at relatively little cost. Knowing more enables individuals to better evaluate whether a job opportunity will match their profile. Similarly, employees will primarily refer jobs to individuals in their network who they think will make a good fit with the job and the company. Employers thus reduce the risks inherent in the recruitment process by relying on networks (Holzer 1987). Reviews of empirical studies show that the majority of jobs tend to be found through networks and that the importance of networks varies only slightly according to the gender, race and sector of those involved (Ioannides and Loury 2004; Montgomery 1991). Jobs received through networks tend to be better fitted to the education of the applicant and offer better career prospects (Franzen and Hangartner 2006).

In doctoral programmes, developing networks has increasingly been promoted as a transferable skill that can be deployed in a wider context than the specific area the students have been studying and that can thereby increase their employability (Sinche et al. 2017; Kyvik and Olsen 2012). In addition, industry partners are increasingly involved in doctoral education, mostly by funding and hosting industrial PhD programmes (Roberts 2018; Benito and Romera 2013; Wallgren and Dahlgren 2005). This involvement of industry contributes towards fostering networks at the university–industry interface and arguably plays a role in facilitating the matching of PhDs' skills with the demands of industry, thereby smoothing the transition from academia.

The transition could be viewed as a move from the academic internal labour market to an industrial internal labour market. Internal labour markets (ILMs) are the institutional rules and procedures that govern the employment relationships within an organization, such as recruitment, training and the price of labour (Doeringer and Piore 1985). ILMs are hence distinguished from the external labour market (ELM), which is directly affected by macro-economic variables. However, ILMs and ELMs can be combined to form an extended internal labour market, when, for example, recruitment channels deploy employees' networks to recruit additional workers (Manwaring 1984).

This tendency to rely on internal networks is in line with March's (1991) argument that organizations, when looking for new resources or markets, prefer to exploit internal resources to which they already have access, rather than exploring new ones. Lam (2007), studying employment at the university–industry interface, took this concept a step further, arguing that ILMs' boundaries between two sets of organizations become blurred when career and knowledge flows across

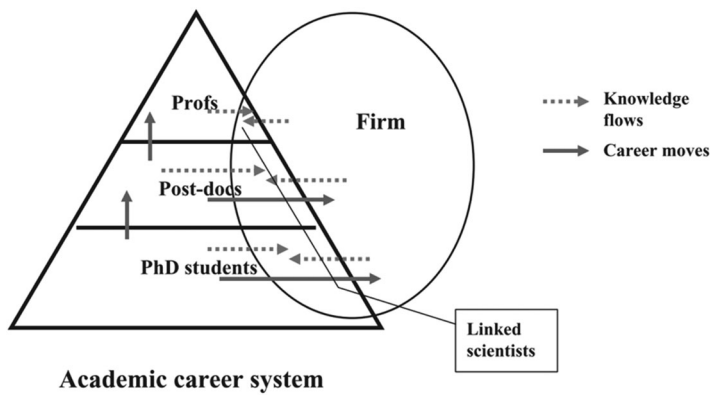


Figure 1. Career and knowledge flows across the academia–industry boundary. Source: Lam (2007, 1011).

them are supported by the creation of an overlapping space (Lam 2007), i.e. the concept of overlapping internal labour markets (OILMs, see Figure 1).

The OILM concept explains the forms of career models emerging from industry–university research and development (R&D) collaborations, such as hybrid careers (Cañibano et al. 2018). ‘Linked scientists’ are researchers whose work roles and careers straddle firms and universities: entrepreneurial professors, postdoctoral researchers who play a major role in collaborative projects and doctoral students who are jointly trained by universities and firms by means of varying arrangements. OILMs, drawing on a pool of linked scientists, can help firms in their selection and screening of candidates for possible recruitment (Lam 2007). ‘The idea behind this [OILM] concept builds on that of a firm’s internal labour market, and how it may be extended beyond the boundary of the firm following established recruitment channels and social networks’ (Lam 2007, 1011).

Methodology and data

In order to investigate the role of university–industry networks in the transition of PhD graduates to industry, we employed a multiple case study design. A qualitative approach, based on semi-structured interviews with such graduates, was adopted. This approach enabled a contextual understanding of the university–industry transition and further offered in-depth insights into the social process of networking and its complexities (Eisenhardt and Graebner 2007; Yin 1984). The prospects of obtaining rich data from varied sources and the closeness of researchers to the data were further advantages of the approach chosen.

Interviews were conducted with 31 STEM PhD graduates from six universities in three countries: the University of Lincoln and Loughborough University in the UK, the University of Stavanger and the University of Oslo in Norway, and Linköping University and KTH Royal Institute of Technology in Sweden (see Table 1). The focus on STEM graduates is based on the above-average exposure to industry that these students experience during their studies (Perkmann et al. 2013). Convenience

Table 1. Overview of samples.

	Norway		Sweden		UK	
	University of Stavanger	University of Oslo	KTH Stockholm	Linköping University	University of Lincoln	Loughborough University
Year of establishment	2005	1811	1827	1975	1992	1966
Type of region	Peripheral	Central	Central	Peripheral	Peripheral	Central
Number of interviews	8	2	6	7	5	3

sampling was applied for selecting the countries and universities. Additionally, for each country, universities from both peripheral and central regions were included. Our sample also included both natives and migrants in the selected countries. We are therefore confident that the sample represents comprehensive coverage of the employability dynamics of PhD graduates.

All countries in our sample have experienced a rapid growth in the number of PhDs over the past decade (OECD 2016). This growth could be attributed in part to the Bologna Process, a series of agreements between European countries to ensure comparability in the standards and quality of higher education qualifications (European Commission n.d.). The adoption of English as the main academic language has enabled the internationalization of doctoral education in the Nordic countries, nearly all of which is written in English (Hultgren, Gregersen, and Thøgersen 2014). While the prescribed duration of doctoral education in Sweden is four years – a year longer than in the UK and Norway – delays and extensions are common, which means that PhD education is of a similar duration in these countries as well (EHEA, n.d.).

In Sweden and Norway, the majority of PhD students are employed by the university and receive salaries based on collective bargaining agreements. However, UK salaries for doctoral students often rely on external funding, making for more variability among students and institutions, and the relative wages are generally lower than in the Nordic countries. The differences are also visible in terms of status, supervisor–student relationships tending to be more hierarchical in the UK than in the Nordic countries.

Contact details of the PhD graduates were retrieved through supervisors, university websites and LinkedIn profiles, and the graduates were invited by email to participate in a 30-minute Skype or face-to-face interview in English. The semi-structured interviews were conducted with the help of an interview guide (see Appendix 1), which included a set of general topics and several specific questions to ensure comprehensive coverage of each topic. The recordings of these interviews were subsequently transcribed. The analysis consisted of two steps: first, the interviews were summarized in a table to provide systematic oversight of the findings in several areas of interest. Individual transcripts were then analysed, after which the individual insights were synthesized to obtain an overall understanding of the data collected.

The data collected illustrates that myriad factors influencing the transition from academia into industry for PhDs. Most commonly, the industry destination was observed to contrast with doctorands' *a priori* career goal of remaining in academia. Only 14 out of the 31 informants wanted to be in industry from the start – six of them being from the Norwegian sample – and two had had no firm plan. Notably, only one person (out of 10 informants) from the Norwegian sample wanted to remain in academia from the beginning of the PhD. Generally, this redirection of career trajectory was attributed to factors such as *a lack of career prospects* in academia, *instability/insecurities* involved in working on a contract basis and *family situation*.

The majority of our interviewees moved to industry directly after graduation, many of them acquiring the position before their graduation. Other PhDs stayed in junior positions in academia before making the move to industry. Some of our interviewees even turned down an academic job offer to pursue one in industry – these interviewees had *lost interest* in an academic career after their first-hand experience during their PhD.

All informants ascribed some relevance of their PhD education, specifically the various disciplines of their research, to the industry they were working in. However, their jobs did not necessarily match their qualifications. One group were carrying out jobs that were within their research fields and for which a PhD degree was a requirement. A second group, though working in similar fields to their areas of study, explained that those jobs could equally well have been performed by people with a Master's degree in the same field, indicating that a PhD was not always an essential requirement for the specific job in industry. Another set were engaged in related research industries where they applied theories, methodologies and tools similar to those they used during their studies, although to very different concepts and contexts. Yet another set attributed the relevance of having a PhD to the skills they acquired and not necessarily the subject they studied. This implied

that, even in unrelated fields, some generic skills acquired during their studies proved useful (see also Appendix 2).

Empirical findings

The role of networks in the 'academia-to-industry' transition

In the process of moving to industry, networks seemed to play a more or less important role, depending on the disposition of the students at the time when they were looking for a job. With the end of their studies imminent, the student would begin to explore various life paths after obtaining a doctorate. It was apparent from our data that the search for a job position was mostly directed by their area of study. If positions were available, '*interesting*' and provided a '*good overlap*' with their interests, they would take advantage of the opportunity. An interplay between the *personal network* of informants and a more *extended network* of their associates was apparent. Interviewee NOR-2 explained this:

Actually, when we visited these conferences, and sometimes it was a professor who was visiting, not me. [...] He presented my work and then [researchers in the audience] were saying that they were also dealing with the same problem. Then he gave me their numbers and I contacted them. [...] it was actually a mixture of my network together with the professor's network.

Personal networks

The personal network refers to links that were individually known to informants and that might enable them to transition into industry without having to tap into the network of someone else in their wider network. This included networks initiated during the PhD, as well as network ties that were established during prior work experience. In some instances, relying on personal networks was evident, as in the following instance:

In that sense I had a collaboration with them but I applied [for the job]. I didn't really apply for a job. I guess I found a person whom I started talking to and then they ended up offering me a job. (SWE-07)

This was observed both in the case of collaborative (*research carried out with industry partners*) and non-collaborative doctoral studies. These personal network connections were seen to consist of either industry or academic contacts. Apart from existing connections (academia or industry), the graduates were also found to have initiated new connections that led to employment in industry. These links extended beyond the period of PhD education to include links such as colleagues from previous education. As UK-5 put it:

I had a colleague from London South Bank, where I did my Master's, who was the technical manager in that area. When I was in the UK looking for a job opportunity, I contacted my colleagues, and she gave me the opportunity.

Extended networks

Additionally, we isolated an external network of wider university and industry connections that played unique roles in the graduates' industry employability. This was mostly evident when a personal connection of the graduate referred them to another person to increase their job prospects. Some PhD graduates were, however, reluctant to use the network of fellow academics and preferred to rely on their own network, as NOR-4 explained:

I would not use it [the network built during the PhD] for finding jobs but it will be more on the technical side [for exchange of knowledge].

Our data showed that academic supervisors or principal investigators (PIs) rarely played a direct or active role in the transition to industry. The participation of PhD supervisors was peripheral and they were often relegated to the role of a referee in the recruitment process. Only in two cases did a collaboration initiated by a PI lead to the recruitment of his PhD student: '*... he went to my*

university ... he told my supervisor and then my supervisor got me to go for their interview' (UK-9). In the other cases where help had been sought from supervisors, the opportunities within the Pls' network were seemingly non-existent.

Further, none of our informants reported any specific help from their universities in transitioning into an industry job. However, belonging to a research group that had enjoyed some collaborations with industry gave access to some research-relevant industries, as seen in the following quote from SWE-12:

(Interviewee) On paper, [my PhD] was in coordination with Saab, I had quite some things with them to do, from my personal viewpoint I would say nothing of what I've been studying has been applied [laughs], so there must be a total failure somewhere, but, yes, I mean, it was one of those [...] national research programmes, so normally it was partnership but ...

(Researcher) So you worked with people at Saab but not the ones that were involved in your recruitment?

(Interviewee) No I didn't work with them, I worked with two guys maybe, but not that much. But I've been encountering some later but we never really worked together; but they all know what I've been doing.

On the wider university scale, various platforms also provided an opportunity to meet industry employers. In the case of one interviewee, it was an event organized by a student association that was decisive in starting the transition to industry: *'And so it was very informal. I happened to meet an HR person at a dinner about a year earlier'* (SWE-7).

Outcome of network-aided transitions

In some of the instances where networks were the mechanism through which the transition to industry occurred, positions were 'created' for the doctorate holders. In this way, networks not only facilitated the transition to industry but also influenced the outcome of the process.

The position was there [but] it was not meant to be a position for my scope. When I applied, then they felt that they also need to have someone with my background and my experience, that they made some adjustment in the requirements of the vacant position. (NOR-5)

Most of the PhDs maintained their academic network when transitioning to industry. In some cases, this was more social in nature, while in other cases there was also academic content, in the form of part-time academic positions and/or co-publication relationships. Some of the PhDs may have maintained this academic involvement because they believed it might increase their chances of moving back to academia at a later stage of their career.

Overall, the kinds of network ties and their importance for the transition of PhD graduates to industry varied considerably. Personal networks were more prominent than extended networks. Individuals took advantage of their existing networks or forged new ties. Depending on their particular interests, they used both explorative and exploitative means to aid their job search. The various channels that emerged from our analysis are summarized in [Table 2](#).

Inter-regional mobility

The search for an industry job resulted in half of the informants (15 out of 31) leaving the region (or country) where they obtained their doctorates. Also, we see this distinction in mobility, with graduates in Scandinavia more likely to stay in the region, whereas most graduates in the UK moved to

Table 2. Network-aided transitions of doctorate holders from academia into industry.

	Personal networks	Extended networks
New ties	Individual's attitude to searching and preferences: <ul style="list-style-type: none">– Exploration– Exploitation	Pls' networks Research group links Wider university links Industry links
Existing ties	Formed before, during or after PhD education	

obtain employment. Although these findings are in line with the higher labour mobility in the UK than in Scandinavia, the differences could also be explained by the fact that the UK PhD graduates had already moved before – which is understood to increase the likelihood of moving again. The UK graduates themselves mainly ascribed their reason for moving to a lack of employment opportunities in the region of study. In these cases, they could not see a regional career path before them and were more inclined to fall back on industry or academic networks built before, during or after their PhD. This was highlighted by UK-4:

To be honest, that time I did not get any opportunity in my field and there was no vacancy actually. But, if I got any opportunity during that time ... because I was living there for four years we had some kind of social relationship with people and also we know lots of people there. It would have been good for us to stay there ... I did my master from [anonymized university] before, so I already knew the place and that's why I came to [the same place] after my PhD.

One reason for the absence of relevant local network connections could be that the development of such a network is a long-term process and is hard to develop when starting from scratch as a newcomer to the region. The Sweden sample was characterized by nearly equal proportions of persons who left or stayed in their respective regions. With a very high exposure to industry during the PhD, the tendency was to access these industry contacts for their transition, as in the case of SWE-9:

[My first job in industry] was very tightly connected to my PhD project. The company I work for now, they were the main sponsor of that project. But I was not an industrial PhD, so I was employed completely by the university. [...] basically, they asked me if I wanted to work there [after my PhD].

To that extent, a regional career path was visible. Additionally, the majority of informants were likely to transition into industry after some time working as a post-doc in academia. In our Norway sample, a regional academic path was prominent. Pre-PhD industry networks seemed to be highly influential on the career moves and nearly all interviewees remained in the regions where they had received their PhD education. However, personal factors related to family also drove their mobility.

Most of the PhDs in Norway and Sweden were familiar with their respective regions before entering their PhD position, while majority of the interviewees from the UK migrated for study purposes, having kept more of an open mind with respect to the geographical location of PhD programmes. Interviewee NOR-10 explained how his existing network in his region helped him land his PhD position:

I was actually based here when the position was advertised and I knew one of the people from the companies who were sponsoring the [research centre]. I actually came to know about the position through him. He happened to be one of the interviewers from my previous company where I was working in Stavanger. I got the job in that previous company because of him, then he moved out and then we met and then he suggested that the sector has been just established and they're going to post position for many PhDs.

With regard to the motivations to study at the various institutions, the interviewees fell into two main groups: first, those interested in studying at a particular university and, second, those who were more interested in a field of research than in the university that offered it, as emphasized by UK-2: *'I would be lying to say it was the place. ... I liked the project, it sounded cool and I was accepted.'* Specifically, for those interviewees who knew from the start that they would opt for an industry career post-PhD, the location of the university appeared to be important – if the industries of interest were accessible.

Country specificities of network-aided transitions

Our data reveal country-specific dominant patterns, in terms of the characteristics and tendencies of university-to-industry career transition, as follows:

- In Sweden, doing a post-doc was quite common; and PhDs' academic networks seemed to drive the *academic* career vertically. However, a prolonged stay in academia weakened the ties to pre-PhD industry networks. Overall, PhD students have a relatively high exposure to industry and their

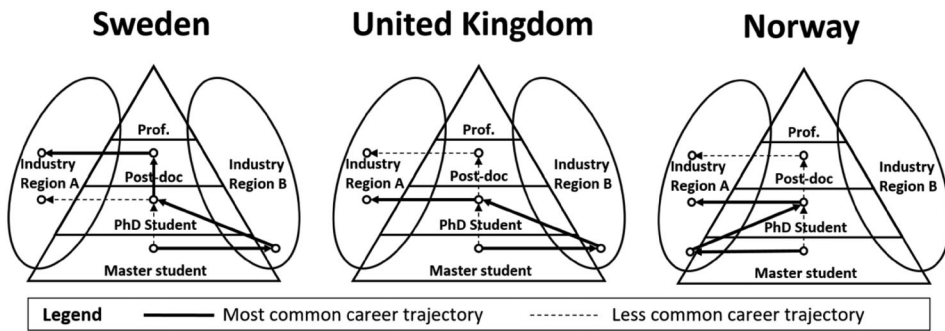


Figure 2. Country-specific dominant patterns of transition of doctorate holders from academia into industry.

industry networks once they graduate are mostly different from their pre-PhD industry networks. Finally, regional career paths are quite noticeable.

- In the UK, a post-doc is seen more as an option than as a preference. Individuals' academic and industrial networks change markedly before, during and after the PhD, owing to quite high geographical mobility. If students are exposed to industry during their PhD studies, this has a significant impact on transferable skills, and the existence of a firm-centred OILM during PhD education often functions as a network mechanism for post-PhD careers.
- In Norway, choosing a post-doctoral contract is less common than in Sweden. PhDs' industrial networks built before they embark on their doctoral studies seem to have an important influence on their career moves. Working in industry after gaining a Master's but before starting PhD studies is quite common. However, exposure to industry during the PhD does not seem to be that high. Regional career paths are noticeable. Nevertheless, it is worth highlighting that most of the PhDs in the Norwegian sample may have been affected by the recent downturn in the oil industry, disrupting the observed transition model; that is, some students who had worked in industry prior to the PhD and chose to return to further study when they lost their jobs. Finally, the existence of a firm-centred OILM prior to the PhD often functions as a network mechanism for post-PhD careers.

Figure 2 schematically summarizes the above-mentioned country-specific trends in a model based on Lam's (2007) OILM framework.

Discussion

From our observations, it is evident that different types of networks come into play in the industry employability of PhD graduates. First, the personal network connections of the PhD graduates were important, both in the case of collaborative and non-collaborative PhDs. By 'personal network', we refer to the graduates' *own* links that *directly* led to employment in industry. These personal network connections were observed to consist of either industry or academic contacts with whom the graduate had existing connections prior to job search, and extended beyond the period of PhD education (e.g. where previous colleagues from Master's programmes played a role in their landing employment).

Apart from their pre-existing connections, the graduates also initiated new connections that led to employment in industry. Contrary to Mangematin's (2000) observation that PhDs generally do not possess the requisite networks or experience to explore non-academic options, it is clear from our research that certain PhD graduates not only have the requisite networks but also initiate the necessary connections and may actually prefer to rely on their personal networks. Future research could explore whether this could be linked to the emphasis put on networking skills in doctoral education in the past decade.

Second, there was evidently an external network of wider university and industry connections who could also play unique roles in finding jobs in industry for graduates. In either case, the network tie could be a new or an existing connection in the graduate's network.

According to Lam (2007, 2011), professors, post-docs and PhD students fulfil their distinct roles at the university–industry interface. While professors are conceptualized as the focal points of these links, post-docs and doctoral students are considered the 'growing' and 'hybrid' categories of linked scientists. Thus, although professors play a central role in this area, evidence suggests that their influence in the employability of the PhD graduates in industry is peripheral. Accordingly, it has been reported that professors – or PIs – often lack the networks in industry that could contribute to industry employment of their students. Indeed, they usually lack knowledge of career opportunities that may exist in industry (Golde 2005). As our data showed, their role in many cases was confined to providing references to support their students' job applications.

It has been suggested that the increasing blurring of university–industry boundaries as a result of collaborations (Thune 2009; Roberts 2018; Benito and Romera 2013) is likely to yield more job opportunities for PhDs in industry. In particular, university–industry collaborations may serve as a platform for the selection, screening and subsequent recruitment of PhD graduates into firms (Lam 2007). In that case, it would be expected that PhD graduates who were involved in collaborative projects (for their PhD studies) enjoy a smoother transition to industry employment, especially if facilitated by PIs. This is, however, not explicitly observed from our evidence. For example, the transition to industry of both groups of PhD graduates (from non-collaborative and collaborative PhDs) was not facilitated by PIs.

According to Hancock and Walsh (2016), doing a PhD may mean forgoing other training opportunities relevant for non-academic jobs. Similarly, we found that in many cases the PhD qualifications are indeed more field-specific than industry jobs would require. Industry opportunities tend to assume a not-too-specific nature and do not necessarily call for highly specialized scientists. We suggest that this creates a mismatch that the extended university–industry networks cannot always overcome. Contrary to Hancock and Walsh's observation, though, we also find that the PhD education actually equips graduates with other industry-relevant skills. When they are employed in industry, they offer an edge, not necessarily the merits of a field-specific PhD qualification but a wider set of qualifications and skills, such as those related to management. In cases where hiring is based on the field-specific expertise of the graduates, the creation of new roles is observed. Moreover, PhD degrees are often not a 'necessity' for industry work (see Appendix 2) but are sometimes useful for work progression once hired, or may lead to the creation of new roles and positions in companies.

The dynamic nature of doctoral candidates' attitudes and interests needs to be considered too. Individuals who pursue a PhD reportedly have a taste for science and those who lose interest in research during their studies are more likely to pursue industry jobs (Sauermaun and Roach 2012; Hayter and Parker 2019). While this change in career preference is evident from our study, the destination of PhD graduates (i.e. industry or academia) is also subject to whether they adopt an 'exploration' or 'exploitation' mode with regard to opportunities. With the increasingly low likelihood of acquiring academic jobs, non-academic destinations are not simply a preference but a necessity for the PhD holder. In such cases, the absence of existing networks to exploit – as the candidate's current networks may be mainly of an academic nature – leads to an exploration of new opportunities by initiating the establishment of networks with industry.

Conclusion

The concept of OILMs was employed to explain the way in which doctoral graduates benefit from the extended networks of academics around them in making the career transition to industry. The findings from the study indicate that, in the academic labour market too, networks play an important role in facilitating labour market matching processes. The interview data demonstrate that OILMs,

when seen from the academic side of the network, play a rather peripheral role in facilitating the career transition of doctoral graduates. On the other hand, from the industry side of the network, OILMs, in the form of connections with individuals in industry known to graduates from their networks established before or during their studies, do play a positive role in their transition from academia. What our study shows, therefore, is that the personal networks of doctoral graduates intertwine with university–industry OILMs, which can facilitate a move to industry.

Nevertheless, contextual specifics make a difference with regard to the extent to which personal networks of doctoral graduates overshadow the OILMs. In a context like the UK, where the mobility of doctoral applicants and graduates is very high, the personal networks were sparse, making it less probable that such networks intertwine with OILMs around the graduates' university. On the other hand, in a context such as Norway, the geographical closeness of the pre-PhD and through-PhD personal and professional networks of graduates helped them considerably to intertwine those networks with the OILMs, which were in fact mainly formed between their pre-PhD employers and their alma mater. In the case of the Swedish interviewees, personal and professional networks became updated during their studies, forming an OILM that later was used for the transition to industry.

Overall, there seems to be a meaningful level of relationship between doctoral graduates' history of geographical mobility and the extent to which they exploit OILMs. Our data show that, the less the geographical mobility during the pre-PhD and post-PhD periods, the greater is the likelihood of benefiting from the intertwining of personal networks with the OILMs. Nevertheless, regional job market characteristics condition the above statement. As our Norwegian cases show, the possibility of formation of OILMs between university and industry is largely influenced by the industrial structure of the region where the university is located. These observations corroborate the findings in the literature on job (mis)match and spatial mobility, which indicate that 'geographical characteristics are likely to affect labour market outcomes such as match or over-education' (Iammarino and Marinelli 2015, 2). We conclude that university–industry OILMs can help facilitate the transition of doctoral graduates to industry when graduates actively explore such spaces through their personal networks, but regional industrial characteristics also significantly influence the intensity of OILMs and hence the OILMs' potential usefulness for job searching and matching.

This paper contributes to the literature on university graduates' career paths, specifically those of doctoral graduates, as well as the role of social (and professional) networks in job matching. Using the concept of OILMs made it possible for us to combine and establish a link between these strands in the literature. The findings of our study are aligned with Thune (2009), who, based on a review of empirical literature on graduate student–industry collaboration, asserted that it is predominantly the individual characteristics of doctoral graduates, rather than their collaborative experiences during their PhD education, that can explain differences in their career trajectories. In a similar vein, our analysis made it clear that the OILMs, while providing a structure for exploring career transition opportunities, do rely on the agency of these job seekers to actualize and deliver their potential. In other words, it is when the candidates activate their own networks and intertwine them with the networks taking shape within OILMs that university–industry extended networks (extended internal labour markets) function best in terms of facilitating a career transition. At the same time, however, the contextual factors such as the industrial structure of the region where the universities are located and the degree of interaction between university and industry influence the OILMs' potential for enriching agents' individual networking initiatives.

A practical implication from these results is directed at doctoral researchers and graduates who seek to pursue a career in industry after doctoral education. As indicated above, there seems to be a significant role attached to the agency or, in other words, the deliberate and conscious initiative of the doctoral graduates in activating the potential of university–industry extended networks (OILMs) is key to their success in finding a job in industry and successfully transitioning to it. Also, a policy implication relating to collaborative doctoral programmes can be drawn from our observations. In order for such programmes to deliver more career-relevant results, it seems to be essential to design and structure the collaboration terms in such a way as to maximize the networking

opportunities for students. Our observations showed that the firm side of OILMs play a more influential part in providing career-relevant networking opportunities than the academic side.

The findings of our study need to be understood with certain limitations in mind. University–industry OILMs are not formed solely in the STEM fields, although they may take shape more clearly in these fields. Hence, further research might explore whether our findings apply to doctoral graduates from other academic disciplines. Furthermore, our cases were limited to a sample of doctoral graduates from a few universities in the UK, Sweden and Norway. The importance and the functioning of personal networks can change based on the size of informal networks (cf. Calvó-Armengol and Zenou 2005) and their influence in finding a job in different countries and cultures. Accordingly, further research is needed to look into the relevance of OILMs for the job transition of doctorate holders from other geographical and cultural contexts.

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ORCID

Eloise Germain-Alamartine  <http://orcid.org/0000-0003-1188-4422>

Rhoda Ahoba-Sam  <http://orcid.org/0000-0003-2869-9856>

Saeed Moghadam-Saman  <http://orcid.org/0000-0001-6715-7924>

Gerwin Evers  <http://orcid.org/0000-0001-5762-2589>

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Appendix 1. Interview guide.

Theme	Question	Purpose
Demographics	Age The time when the PhD was completed Field of study/research	To understand the background
Current job	Is present work related to field of study? Describe in a few words your current job Is there any link with your PhD? Are your PhD studies useful for your current job? How? Was your PhD an industrial PhD? Do you speak the local language?	To understand the background
Path to industry	When did you graduate (PhD)? When did you leave academia for industry? Have you always wanted to work in industry? <ul style="list-style-type: none"> This kind of industry? Why? If changed? Why? (who and what influenced it? How did the influence happen?) 	Historical footprints could have an effect on a person's decisions To see if will / inspiration comes from someone in particular (thus from network) or not
	Did you work in industry prior to your PhD? <ul style="list-style-type: none"> Have they returned to the same or similar industry? No– What/who could have influenced a change in industry? Yes– How has the PhD influenced your work now that you are more educated? 	To see if network was built prior to the PhD
Prior connections	How did you find your job (the one of transition)? Did your job exist or was it created for you? Were you referred to this job? Did you know anyone in your job prior to the appointment? How? Who? <ul style="list-style-type: none"> Did you know this person during your PhD? Did your PhD supervisor (or any academic) play a role in this transition? 	Influence of network on landing industry employment (connections to people, places and institutions)
Feedback loop	Would you want to go back to Academia? Why? Who in academia have you remained in contact with? (why?)	To get the interviewee to be reflective, assess influences, etc.
Network	Have you built your network during your PhD studies or before? What type of network? (academia, industry) Is your network the same as your supervisor's? Do you still use the network you built during your PhD studies? Do you think it could be useful to find a job? How?	To understand the background + To get the interviewee to be reflective, assess influences, etc.
Region	Why did you choose [university] for your PhD? Why did you leave [stay in] the region after the PhD? Would you have liked to stay in [leave] the region? Were there job opportunities for you in the region? If you had been referred to a position in the region, would you have accepted it instead of your current job?	To understand the background + To get the interviewee to be reflective, assess influences, etc.

Appendix 2. Perceived relevance of PhD studies to industry jobs.

Variants observed	Relevance of PhD to job	Area of relevance	Required PhD degree
1	Yes	Same research field	Yes
2	Yes	Same research field	No
3	Yes	Similar/related research field	Yes
4	Yes	Similar/related research field	No
5	Yes	Different research field - Skills acquired from PhD relevant	No