An impact analysis of regional industry–university interactions

The case of industrial PhD schools

Linda Gustavsson, Cali Nuur and Johan Söderlind

Abstract: *The authors discuss Triple Helix collaborations in the context of regional competitiveness. Through an exploratory case study, they identify and analyse the impact of the establishment of industrial PhD schools for participating industry and universities. The study was conducted in Sweden in 2014 and focuses on three industry–university initiatives involving a total of 57 doctoral students, 9 universities and 39 companies. The results indicate that PhD schools based on the dynamics of the Triple Helix can be of great benefit for both industry and regional universities. In addition, the paper identifies critical success factors for industry–university collaborations involving joint PhD education.*

Keywords: *collaborative doctoral education; regional competitiveness; Sweden; Triple Helix; university–industry collaboration*

Linda Gustavsson (corresponding author) is with The Knowledge Foundation, Mäster Samuelsgatan 60, 11121 Stockholm, Sweden. E-mail: linda.gustavsson@kks.se. She is also an Affiliated Researcher with the Department of Industrial Economics and Management, The Royal Institute of Technology (KTH), Stockholm, Sweden. Cali Nuur is also with the Department of Industrial Economics and Management at KTH. E-mail: cali.nuur@indek.kth.se. Johan Söderlind is a PhD candidate with the Department of Learning at KTH. E-mail: johanso2@kth.se.

On the basis that competitiveness is often the outcome of collective knowledge-building processes between academic, industrial and policy actors, in recent decades the Triple Helix framework has been predominant in the debates about regional development (see, for example, Asheim *et al*, 2011; Asheim and Coenen 2005; Cooke and Leydesdorff, 2006; Etzkowitz and Klofsten, 2005). From a regional development perspective, the interactions between the principal Triple Helix actors – industry, policy makers and academia – have come to be regarded as drivers of the endogenous growth policy that has replaced the previous regional convergence models which prevailed decades ago (see, for example, Etzkowitz, 2003, 2012; Huggins and Strakova, 2012; Mueller, 2006; Stimson *et al*, 2011; Stough *et al*, 2011). In the endogenous regional growth paradigm, universities are assigned a vital role in inducing and sustaining regional growth processes by interacting and collaborating with industry and the wider society.

The Triple Helix model recognizes universities as not being limited merely to providing education and conducting research but, rather, as having a wider role which includes generating and attracting talent and facilitating innovation, entrepreneurship and industrial competitiveness (Bramwell and Wolfe, 2008; Florida, 2002; Smith and Bagchi-Sen, 2010; Leydesdorff, 2013;

Meyer *et al*, 2014; Martin and Sunley, 1998; Karlsson *et al*, 2014; Tödtling, 2011). Whilst the policy rhetoric concerning industry–university collaboration has intensified in the last few decades, industry–university interactions are not a new phenomenon (Rosenberg and Nelson, 1994; Swann, 1988). What is new, however, is the conceptualization of these interactions through the Triple Helix model and the recognition that industry–university collaborations are becoming an inherent and essential part of both research and education (Todeva, 2013). Accordingly, there is ongoing research and policy debate on how to define and measure these interactions and, consequently, how this should be reflected in public funding, etc. In the context of regional competitiveness, one of the outcomes of the current policy debate on creating and sustaining growth is the greater emphasis placed on the university's role as a provider of trained researchers in addition to graduates.

Using an explorative case study approach, this paper focuses on the impacts on industry and academia arising from participating in industrial PhD schools. The paper is based on case studies of three such bodies at Swedish regional universities. The industrial PhD schools are jointly funded by industry and the Knowledge Foundation, a public intermediary organization (Todeva, 2013) with the aim of strengthening the competitiveness of Sweden's new universities. Our primary goal with the case studies was to generate hypotheses for further research on impacts of collaborative PhD education for participating industry and academia.

The paper is structured as follows. In the next section, we place Triple Helix collaborations in the context of regional development and discuss the literature on collaborative doctoral education. This is followed by a description of the methodology and presentation of the findings – that is, the impacts on participating industry and academia from engaging in collaborative doctoral education. Finally, we conclude the paper by offering hypotheses for further research and highlighting critical success factors for this type of collaboration.

Industry–university collaborations as Triple Helix interactions

Successful collaborations between academia, government and industry – Triple Helix interactions – are considered a key component in knowledge-based economies and societies. The increased importance given to endogenous regional growth (Etzkowitz, 2003, 2012; Huggins and Strakova, 2012; Mueller, 2006; Nuur *et al*, 2009; Stimson *et al*, 2011; Stough *et al*, 2011) has led to expectations regarding the nature and role of universities for regional development. The Triple Helix model suggests that universities can be considered as 'key architects' and even drivers of regional development (Etzkowitz and Klofsten, 2005). In the context of regional development, this has been referred to as creating 'regional Triple Helix spaces' (Etzkowitz, 2008). However, there are different suggestions in the literature about the role the regional universities play. In many studies, it is the human capital development that is highlighted (Etzkowitz and Leydesdorff, 2000; Gunasekara, 2004). For instance, in an analysis of the Triple Helix model at the regional level in Oxfordshire, UK, Smith and Bagchi-Sen (2010) found that the reliance of industry on the regional university was largely connected to labour market dynamics. This would suggest that human capital formation is a key element in a regional Triple Helix. The Smith and Bagchi-Sen (2010) study found that in regional collaboration, despite the presence of highly ranked research universities in the region, providing higher education was a more a significant factor than access to research.

The findings of Smith and Bagchi-Sen (2010) were in line with studies conducted in Sweden which suggested that local sources of research were not the defining factor or key driver for regional collaboration (Power and Malmberg, 2008). In addition, studies in Canada on university–industry collaboration (for example, Bramwell and Wolfe, 2008) confirmed the importance of these collaborations for generating and attracting talent to the region. Furthermore, the role of the universities in creating ties to global research networks were also identified as important for local and regional economic dynamics (Bramwell and Wolfe, 2008).

In fact, there are studies (compare, for example, Ejermo, 2012; Webster, 2001; Pham, 2000) which showed that regional universities educated for local industry to a greater extent compared to universities in metropolitan areas. This makes local competence matching very important; that is, the competence is relevant for the region that is being developed. At the same time, there are studies which showed that nationally there was a general shortage in matching education with the actual competence needs in industry (Confederation of Swedish Enterprise, 2012). However, there is general agreement that regional universities can be considered regional competence carriers. The importance of academia in providing the competence needed by the surrounding society becomes particularly significant with regard to regional universities.

From an industry perspective, there are several potential benefits arising from industry–university collaboration which motivate industry to engage in collaborative initiatives. Broström (2012) identified four main drivers for such cooperation:

(1) Collaboration for product or process development;
(2) Access to academic networks; in addition to those networks which may lead to solving a particular research problem, sometimes a stronger driver for collaboration is the possibility of connecting with prominent researchers;
(3) Competence development/supply – that is, recruitment possibilities as well as the ability to retain personnel, and to secure research capacity and future supply of human capital; and, finally,
(4) Business opportunities which involve business models such as distributing academic research results and the use of academic experts in product evaluations, or where academia is an important customer group.

Industry–university cooperation can be considered as still being in a fairly early stage of development. A study on academics' involvement in industry–university collaboration (Davey *et al*, 2011) showed that about 40% of academics were not engaged in such collaborations, and 20% percent were engaged only to a small extent. Fewer than 40% of the academics were involved in cooperation to a medium or large extent. In general, there was a stronger focus on research and the commercialization of research in this cooperation, with less emphasis being placed on activities more closely connected to the academic activities, such as curriculum development and delivery (Davey *et al*, 2011).

Collaborative doctoral education

Doctoral education has undergone transformations shaped by shifting societal needs, new research approaches and changing labour markets for holders of a PhD (Malfroy, 2011; Nerad, 2010). A doctoral qualification is no longer viewed as being solely a preparation for an academic career but, rather, as a qualification that is increasingly attractive to a wider employer base (Metcalfe, 2006). Borell-Damian *et al* found, in 2010, that in Europe about 50% of PhD graduates were moving directly into employment outside the academic field (Borell-Damian *et al*, 2010). In light of this changing nature of doctoral career trajectories, there is increasing interest in the training of PhD students for careers outside academia. The focus, therefore, is increasingly on graduate employability and transferable skills; and, consequently, doctoral education programmes organized in collaboration with industry are gaining importance (Borrell-Damian, 2009). Much of the research on collaborative PhD education therefore has come to focus on student experiences and their subsequent careers, and its implications for the future organization of doctoral education (see, for example, Thune, 2009; Wallgren and Dahlgren, 2005).

In the literature focusing on doctoral students in industry–university collaborations, the students are assigned three important roles: in the production of knowledge in these collaborative research projects; in channelling knowledge between academia and industry; and in the establishment of government–university–firm networks, regarded as vitally important (Thune, 2010).

In this paper, the focus is on the experiences of other stakeholders – that is, industry and academia – in collaborative doctoral education. The aim is to identify the results and impacts that these collaborations can lead to for these actors.

The nature, duration and funding for PhD education varies across countries (Botterill and Gale, 2006; Denicolo, 2003; Nyquist, 2002; Park, 2005; Schneider and Sadowski, 2010). Generally, funding of PhD education, not the least in new and/or regional universities, is often a challenging process that involves competition for available funds. While the majority of PhD education might still be funded through faculty fellowships or external funding (for example, research funding bodies such as research councils), there is also an increasing trend in which companies or Triple Helix intermediaries fund industrial PhD candidates (see, for example, Thune *et al*, 2012). The main argument for training industrial PhD students is that this would facilitate technology and knowledge transfer from academia to industry. However, the expected results and impacts for academia in such collaborative schemes are not widely discussed in the literature.

The added interest in industry–university collaboration in PhD education is arguably related to the knowledge-based view on innovation together with the acknowledgement that a majority of doctoral students are destined for careers outside of academia (Borrell-Damian, 2009). There are some collaborative industry–university PhD education initiatives that have existed for some time, such as CIFRE in France, CASE in the UK, the Danish Industrial PhD Programmes and the Marie Curie Actions. Borell-Damian (2009) provided a broad overview of doctoral education in Europe, including the above-mentioned initiatives. She identified a growing trend towards the development of structured doctoral programmes in place of traditional individual study programmes: collaborative doctoral programmes were defined as involving close interaction between a company, a doctoral student and a university. A distinctive characteristic was that industry experts were active parts of the supervisory committee, formally or informally.

Methodology

This study is based on interview and survey data from three industrial PhD schools in Sweden in the following sectors: pulp and paper; production engineering; and automation and robotics. In total, the three PhD schools studied enrolled 57 doctoral students at nine universities and in cooperation with 39 companies. The selection of these particular schools was based on the following criteria: all three schools had been completed at the time of the study and the design of the schools, as well as the financial arrangements, was the same for all three. An important criterion for the selection of the particular cases was also that their design was the same as that of the industrial PhD schools currently running.[1] Structurally, our case studies are exploratory (Stake, 1995, 2000; Yin, 1993): the intention was to identify the benefits that academia and industry can draw from engaging in Triple Helix collaborations of this particular kind. Our primary goal with the case studies was to generate hypotheses for further research on impacts of collaborative PhD education for participating industry and academia.

In total, 18 interviews, involving PhD candidates, companies and universities, were carried out in 2014. The interviewees were selected to be representative for the three participating schools. We therefore interviewed a number of industrial representatives (normally the industry supervisor/mentor), a number of the participating PhD students (now PhD degree holders), as well as the three research school directors (from academia). The interviews were carried out face-to-face, using a semi-structured interview guide which covered topics such as drivers and motivations for engaging in collaborative doctoral education projects, results and outcomes from the collaborative research project, experiences regarding the collaboration as well as the design of the programme (including areas such as supervision, funding and the degree of involvement). A survey, targeting all participants (interviewees excluded) in the three schools, was also conducted which addressed similar questions as the interviews: the response rate was 36% for doctoral students and 23% for companies.

Data analysis

Results and impacts from collaboration can be depicted in an impact analysis where a certain research project/activity is expected to provide certain results (Åström *et al*, 2010). Industry–university collaborations, in our case the establishment of PhD schools, will have both discernible short-term impacts as well as long-term impacts. These can be related to outcomes such as the number of successful graduates, the number of scientific publications, the creation of new knowledge and the establishment of new networks as well as the strengthening of established networks. In Sweden, the Innovation Systems Agency, Vinnova, conducted an impact analysis on some of their research programmes (Åström *et al*, 2010: p 5). Vinnova refers to the different impacts as first order or second order impact, where the latter is noticeable only in a long-term perspective. Further, second order impacts refer to a higher analytical level. First order impact (1–5 years after the termination of a programme) is connected to strengthened competitiveness on the firm level; this involves, for instance, competence development of personnel, increased R&D capacity, networks and recruitment possibilities. Second-order impacts (5–10 years after the termination of a programme) can be seen as an effect of the first-order impacts and to relate to the industry level; this involves factors such as technology transfer within an industry, as well as new firm formation, and industrial renewal that goes beyond the participating companies and industries.

A similar analysis of the effects of collaboration between academia and industry was presented by Damvad (2012). Economic effects from research collaboration can be numerous and appear at various times. Damvad identifies effects at different time levels:

(1) Within 0–2 years behavioural changes, such as strategic management changes and changes regarding university collaborations, can be identified;
(2) Within 1–5 years innovative effects can be identified in terms of, for instance, increased R&D activity or patents;
(3) Within 2–10 years economic effects such as increased productivity or increased employment can be identified; and, finally,
(4) In 5–20 years social effects can be identified through, for instance, socio-economic growth or solutions to societal challenges.

There are many similarities between the Vinnova (Åström *et al*) and Damvad analyses, both in terms of the timeframe in which certain impacts can be expected and also on what level these impacts can be expected. In this study, we used an analytical tool similar to that of Vinnova described above. However, like Damvad, in this paper the chronological dimension is distinguished from the analytical dimension. We wanted to illustrate the impacts over time for two analytical objects – academia and industry. It is also more appropriate to talk about short-term and long-term impacts. Our analytical framework is depicted in Figure 1.

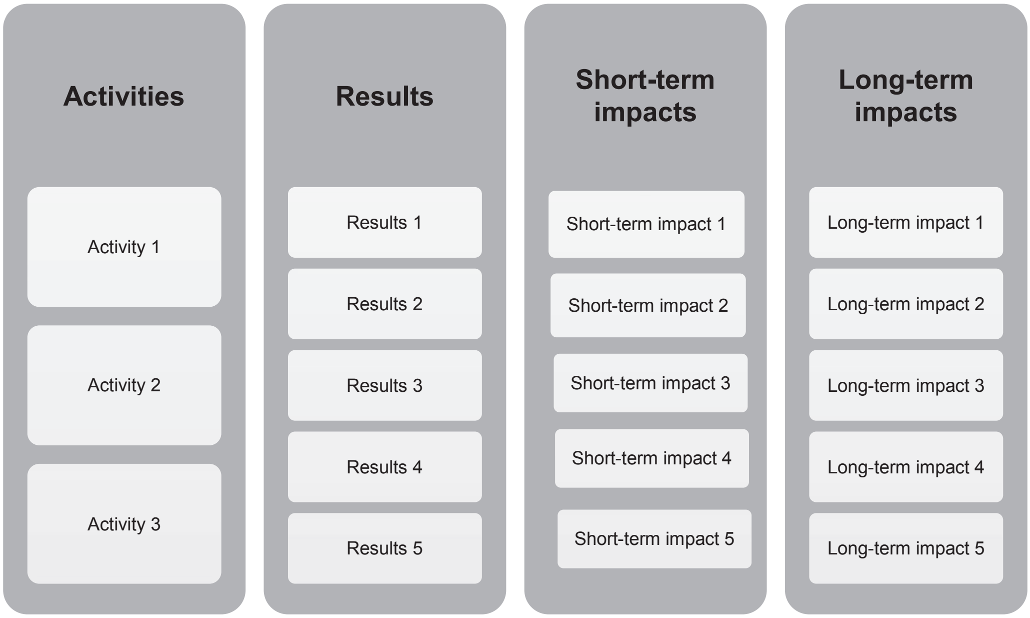

Figure 1. Analytical framework for the study.

Impact analysis of collaborative PhD education in Sweden

The Swedish higher education system has a differentiated structure with, broadly, two groups of universities. First, there is one group of older and relatively well-established universities in and around the major Swedish cities. The second group consists of relatively new universities and university colleges, mainly in medium-sized and industrialized regions. Within the group of new regional university colleges a few have since gained university status. Currently there are four new universities and twelve new university colleges in Sweden. Hereinafter, we refer to this group of new universities and university colleges as the 'new universities'.

The role of the new universities has been clear since their establishment: they are expected to act as competence providers to regional employers and therefore there is a clear emphasis on education rather than research. As a result, research – along with research funding – remains largely with the established universities. According to statistics provided by the Swedish Higher Education Authority (UKÄ) there are profound differences between the established universities and the new universities. The established universities spend 43% of their budgets on education and 57% on research; for the new HEIs, the distribution is 27% for research and 73% on education (statistics per 2012, UKÄ, 2014).

The three industrial PhD schools

The three industrial PhD schools studied were funded by the Knowledge Foundation together with participating industry. The Knowledge Foundation is a research financier funding collaborative research and education initiatives at Sweden's new universities; it could be argued that it is a Triple Helix intermediary organization (Todeva, 2013).

Since its establishment, the Knowledge Foundation has funded more than 2,400 projects at a cost of more than one billion Euros. Its overall mission is to strengthen Sweden's competitiveness; and one important aspect of this mission is to help the new universities create internationally competitive research and education environments and facilitate cooperation between academia and industry. The goal of the industrial PhD schools is to meet the business sector's needs for research expertise in relevant and well-defined areas through collaborative doctoral education. Another goal is to develop the research and education environment of the university.

Participating industry in the industrial PhD schools is required to co-finance the research project (in-kind or otherwise) with at least the same amount as that of the Knowledge Foundation. Most of the doctoral students are also employed by the companies, and they are expected to devote 80% of their time to their studies. Another requirement is that each doctoral student has one supervisor from academia and one from industry. In addition, the industrial PhD schools are required to include several joint activities for doctoral students, collaboration with and between companies, and the development of new doctoral courses that are tailored to the specific research focus of the PhD School. The industrial PhD schools discussed in this paper are as follows.

- *Mekmassa – Industrial PhD school in Mechanical Pulping*. The goal of Mekmassa was to create conditions for efficient use of mechanical and chemical thermo-mechanical pulping in existing and new high-quality fibre-based products through collaboration between academia and industry. The school had three research areas: energy-efficient production, steering of pulp and product quality, and bright paper products. Today, the university has a new industrial PhD school involving some of the same companies as in Mekmassa.
- *CAPE – Industrial PhD school CAPE, Centre for Advanced Production Engineering*. The focus of this school was virtual production development and the need to enhance competence development in industrial production engineering, not least in the light of increasing global competition. This project was coordinated from University West but the school was a joint effort of four universities in Sweden. In contrast to the other two industrial PhD schools, University West did not have its own right to confer doctoral degrees. As a result of CAPE, University West gained rights to confer doctoral degrees within this research area and it is also running a new industrial PhD school within the field of production process technology.
- *RAP – Industrial PhD school RAP, Intelligent Systems for Robotics, Automation and Process Control*. The focus of RAP was on intelligent systems and in particular intelligent robots, sensor systems and simulation. The coordinating HEI was Örebro University and the school involved three other Swedish universities. RAP is now an established PhD school at Örebro University. At the time of writing this case, there were no industrial PhD students but only academic PhD students enrolled.

Table 1 presents details of the duration and scope of the three schools.

Results and impacts from collaborative doctoral education

So, what are the results and impacts that the different stakeholders – more precisely industry on the one hand and academia on the other hand – have experienced from these collaborative PhD schools?

From an industry/company perspective, the motives of participating in industry–university collaboration may vary. For the companies involved in this study the reasons for engaging in these collaborative projects were, among others: building relations with academia; accessing new knowledge and state-of-the-art research; developing internal research and development; and recruiting (securing a present and future base for recruitment). A common characteristic of the companies that participated in this study was that they all had a more or less well defined industrial problem that they needed to solve. For academia, the incentives for engaging in the industrial PhD school are given as: strengthening relations with industry; developing their doctoral education (third cycle education); and to use the PhD school as a means to position their universities within a specific research domain.

Results and impacts for participating industry

On a company level, a direct result of the industrial PhD schools is that of competence creation and retention. As shown in Table 2, 51% of the doctoral students were still in the same company a few years

Table 1. The three industrial PhD schools.

	Mekmassa **Industrial PhD school in Mechanical Pulping**	**CAPE** **Industrial PhD school in Advanced Production Engineering**	**RAP** **Industrial PhD school in Intelligent Systems for Robotics, Automation and Process Control**
University	Mid Sweden University	University West, Chalmers University of Technology, Jönköping University and Skövde University	Örebro University, Mälardalen University, Halmstad University and Skövde University
Duration	2006–2012	2006–2012	2006–2011
Number of PhD students	18	24	15
Number of companies	7	19	13
Non-completed studies	0	2	2
Financial support from the Knowledge Foundation	€1.5 million	€2 million	€1.5 million
Financial support from companies	€3 million	€4 million	€3 million

Table 2. PhD students' employment after graduation.

	Mekmassa	CAPE	RAP	Total	%
Same company	10	8	11	29	51
Same industry	5	8	1	14	25
Another industry	2	0	0	2	3
To academia	0	4	1	5	9
NA/non-completed studies	1	2	2	7	12
Total number of doctoral students	18	24	15	57	100

after graduation and 76% were still in the same industry.

In addition, many of the research projects resulted in new and/or developed products and processes. Because the companies were highly involved in formulating the research projects as well as in the funding and supervision of the doctoral student, there appeared to be strong industry relevance in the projects. According to our interviews, this involvement was crucial for integrating the research project into the actual industrial practice/environment as well as to provide clear goals to the project. The impact of this engagement could be discerned in the number of projects resulting in actual applications that are used and further developed by industry. In RAP, for instance, eight of the doctoral theses resulted in new, or a new generation of, products. These include a robot system for flexible 3D friction stir welding, an integrated system for fault detection in a fleet of city buses, a novel breath-alcohol sensor for non-operative sensors in emergency health care, and unmanned operation of LHD vehicles in mining environments – to mention a few. There were also four research projects that significantly improved existing products, and one project that contributed with important knowledge and competence regarding potential products.

In Mekmassa, too, several of the projects resulted in product and process development. Optimization of the bleach process in the production of cardboard, developing on-line measurement technology to decrease variations in characteristics for mechanical pulp, and image analysis of refinement process fibre efficiency through temperature/pressure increase are all examples of valuable results for the participating companies.

In CAPE, one research project led to the elimination of the use of prototype vehicles in the training of assembly personnel: the research project developed a completely new alternative training concept. Other results included ceramic coatings for gas turbines with lower conductivity and doubled durability, and the development of a new testing method for welding super alloys.

The establishment of industrial PhD schools also resulted in new and/or strengthened contacts –with both academia and other companies. Although contacts with academia were not entirely new – our cases showed that collaboration in the industrial PhD school was usually preceded by previous collaborations or contacts of some sort – in most cases these ties were strengthened. The formal agreement contributed to commitments and formalized collaborative arrangements for both parties in terms of economic resources and human resources (time, personnel etc).

Figure 2 illustrates results and impacts in short-term and long-term perspectives. With regard to the short-term impacts for the participating companies, increased competence is probably the most significant. This has occurred through the knowledge that the doctoral students have appropriated and the new/developed products and processes resulting from the research projects. Our interviews also showed that involvement in these research projects had led to a more systematic and scientific approach to problem solving within the companies. Another benefit that was also raised by several interviewees was increased legitimacy for a product/process gained through, for instance, publications such as scientific articles and doctoral theses. This had resulted in companies being able to strengthen their ties to clients and business partners.

In addition, the establishment of industrial PhD schools had contributed to facilitating new contacts within the industry as well as strengthening collaborative networks. In this context, we observed how participants had engaged in bilateral research collaborations between participating companies as well as larger, industry-level research schemes. The networks and collaborations that the industrial PhD schools generated also contributed to technology transfer. This had taken place because of contacts established through participating in the PhD schools and through the mobility of graduates from one company to another, or from the company to academia. There were also examples where companies had found results from other research projects within the industrial PhD school which they could use to develop their products or processes.

In a longer-term perspective, the collaborations have had an impact on identifying new business opportunities. Our interviews revealed examples where

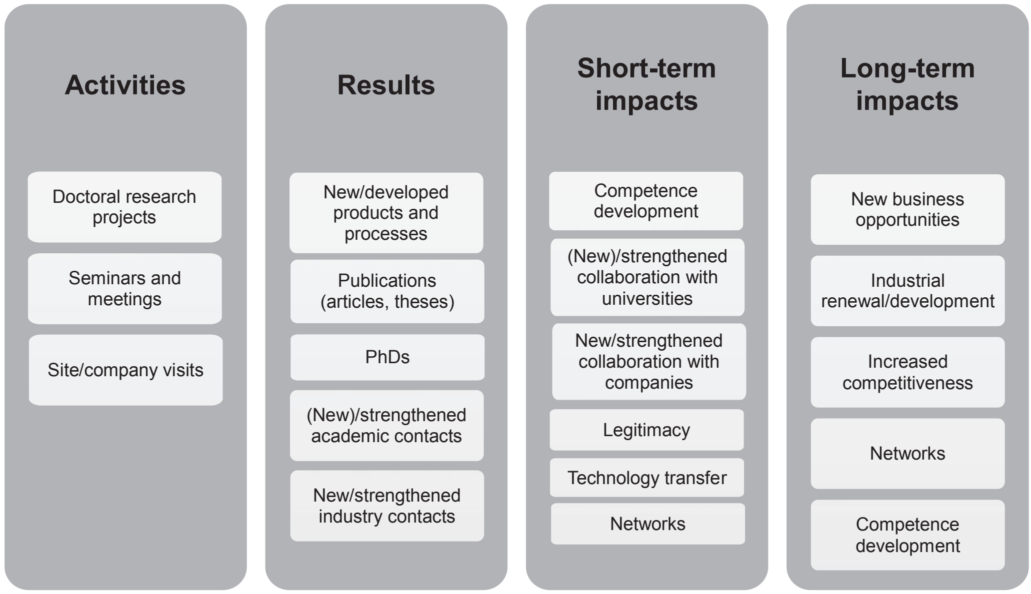

Figure 2. Results and impacts from the short-term and long-term perspectives for industry.

mobility of the doctoral students within the same industrial sector had played a key role in new business opportunities. For instance, there were examples where one company's PhD student started working for a customer, moving from being a person developing the product to the person purchasing it.

In general, the doctoral students we interviewed in this study highlighted the importance of networking with other doctoral students. These strong networks between the doctoral students remain in place and can have impacts long after the termination of the industrial PhD school.

However, whether the PhD schools have increased competitiveness and industrial renewal/development is open to speculation because we do not have results to support this statement (yet!). This caveat notwithstanding, the increased competence level, the strengthened academic environment, the networks both on individual (between doctoral students) and on company levels provide good foundations for further development and sustained competitiveness.

Finally, the future supply of competence for the companies was a very important positive impact of the industrial PhD schools. Interactions through the initiation and running of the schools had resulted in contacts which enabled companies to host graduate students who were writing their project theses; to develop research collaborations; and to realise recruitment opportunities.

Results and impacts for participating academia

For the participating new universities, the industrial PhD schools undoubtedly resulted in not only an increase in PhD graduates, together with a large number of publications, but also in strengthening the contacts between the new universities and industry. Some of these relations were new, while most contacts had been enhanced and further developed. Thus, in the short-term, for the participating new universities this has resulted in continued research collaboration, as well as the initiation of new industrial PhD schools. The industrial PhD schools have also contributed to capacity building of academia together with increased insight into the challenges that industry faces.

Figure 3 shows the results and impacts for short-term and long-term perspectives. Based on our interviews, it is clear that one of the major impacts the industrial PhD schools have had on academia is building and strengthening the research environment. In real numbers, these projects have made the research environments grow. They have also helped to improve the level, as well as the relevance to the surrounding community, of the research that was undertaken. For example, for one new university, a positive impact is that it has gained the right to confer doctoral degrees. According to our interviews, gaining the right to confer degrees was decisively underpinned by the presence of the industrial PhD school. Similarly, the industrial PhD school has been a vital part of building a strong centre in production technology – one of the strongest in Sweden – which today employs around 40 people.

Thus the industrial PhD school collaboration has enabled the participating academic environment to strengthen its position nationally and internationally in the specific research areas. It also makes the research environment more visible to industry, making the

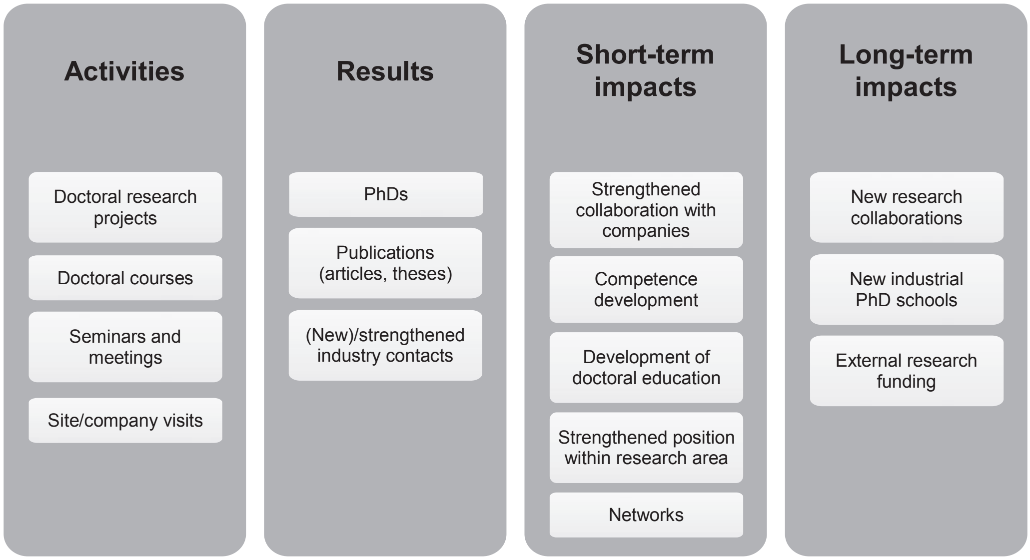

Figure 3. Results and impacts from the short-term and long-term perspectives for academia.

initiation of research collaborations with companies easier.

In a longer-term perspective, both University West and Mid Sweden University now have new industrial PhD schools which in part are continuations of the previous ones.

Conclusions and critical success factors

This paper has discussed the benefits that new universities and industry can draw from Triple Helix interactions in the shape of collaborative PhD education; and, using a case study of three industrial PhD schools, we have provided an impact analysis. In Sweden, and other old industrialised nations, the process of globalization as well as the knowledge economy paradigm has posed challenges to regional development. Unlike the old regional convergence which centred on Keynesian regional multipliers (Nuur and Laestadius, 2010), the prevailing endogenous regional policy assigns universities a key role in contributing to knowledge building for regional competitiveness. The expectation is that regional Triple Helix collaborations will facilitate innovation, knowledge creation and capability development as well as entrepreneurship.

Drawing on the three case studies, we can offer some important conclusions about the impacts of industry–university collaboration through industrial PhD schools, for participating companies on the one hand, and participating academia on the other. Based on our findings, the following hypotheses may be proposed.

A. Industry–university collaborations in industrial PhD schools can result in highly valuable – and often commercializable – knowledge. The collaborative doctoral research projects are often needs driven and derived from real industrial problems. The involvement of industry in defining the research problem, as well as the continuous involvement of industrial partners throughout the project, is a very important part of the success of these projects. Our case studies showed that the outcomes include, for instance, new product development, improved processes and new training methods that have benefitted the companies involved. In addition, the numerous examples of continuous collaboration after the termination of these three industrial PhD schools are evidence of the value these industrial PhD schools can have for industry.

B. Collaborations in industrial PhD schools can be a crucial source of human capital for regional industry. From our case studies, the clearest evidence is the 45 researchers that are now working in industry. We have also shown that a majority of these PhDs remain in the same industrial sector. Thus we can conclude that these industrial PhD schools are important instruments for development of industrial competence. Collaboration in doctoral education is a good way to ensure that it is competence which is highly relevant for the involved industry that is developed. As such, it is a good measure with which to address the problem of competence matching.

C. Collaborations in industrial PhD schools can have very positive impacts for the participating new universities. These collaborations can strengthen substantially the academic environments in several ways – for example, a significant increase in the number of doctoral students enrolled, a strengthened collaboration with regional industry and a boost in the competence level of the faculty. It is also important to emphasize that industry–university collaborations are not a one-way knowledge and technology transfer, where academia shares its knowledge and research with industry. It is most certainly a two-way exchange of both knowledge and technology.

D. There is potential for these dynamics gained through industry–university collaboration to be sustainable in the long term. While it is difficult to predict the future, we note that the established networks between industry and academia can create a strong foundation for continuous exchange of knowledge and technology, as well as future collaborations in both research and education activities. This, we believe, can result in a positive cycle, helping to sustain A, B and C above.

These proposals are based on case studies in the form that these industrial PhD schools represent – not collaborative doctoral research in general. Further studies are required in order to be able to draw more general conclusions regarding the impact of collaborative PhD education.

Finally, we can identify some critical success factors for university–industry collaborations of this sort – that is, critical success factors inherent in the form and design of these industrial PhD schools. Company buy-in and support from company management is a prerequisite in the design, and a critical success factor (see also Wohlin *et al*, 2012). This is in line with Borrell-Damian's (2009) study which identified the importance of the organizational level that is engaged, which also reflects the degree of organizational commitment. Strategic engagement from both the university and industry is an essential component for success.

Another critical success factor is a collaboration champion at the company (see Wohlin *et al*, 2012). Furthermore, careful recruitment of motivated PhD students with an interest in integrating and brokering knowledge from industry and academia, and previous experience within the participating firms from research and PhD education, are factors that contribute to successful collaborations (see Bienkowska and Wallgren, 2012; Thune, 2009). Lastly, a final and essential success factor that we can identify is the joint formulation of the research project. This, together with the shared supervision of the doctoral student, ensures that the research is highly relevant and beneficial for both the university and industry.

Acknowledgements

This study was made possible by the Knowledge Foundation and through a generous grant from the Marianne and Marcus Wallenberg Foundation (Number MMW 2013.0194).

Notes

[1]Currently, there are ten industrial PhD schools running which are co-founded by the Knowledge Foundation and industry.

References

Asheim, B.T., and Coenen, L. (2005), 'Knowledge bases and regional innovation systems: comparing Nordic clusters', *Research Policy*, Vol 34, No 8, pp 1173–1190.

Asheim, B.T., Boschma, R., and Cooke, P. (2011), 'Constructing regional advantage: platform policies based on related variety and differentiated knowledge bases', *Regional Studies*, Vol 45, No 7, pp 893–904.

Åström, T., Jansson, T., Mattsson, P., Faugert, S., Hellman, J., and Arnold, E. (2010), 'Effektanalys av stöd till strategiska utvecklingsområden för svensk tillverkningsindustri' ['Impact analysis of support for strategic development areas for the Swedish manufacturing industry'], Vinnova, Stockholm, http://www.vinnova.se/upload/EPiStorePDF/va-10–07.pdf (accessed 04 December 2015).

Bienkowska, D., and Wallgren, L. (2012), 'Industrial graduate schools: university–industry interaction for development of absorptive capacity', *XXIII ISPIM Conference, Barcelona, 17–20 June*, *ISPIM (International Society for Professional Innovation Management)*, Manchester.

Borell-Damian, L. (2009), *Collaborative Doctoral Education: University–Industry Partnerships for Enhancing Knowledge Exchange*, EUA, Brussels.

Borrell-Damian, L., Brown, T., Dearing, A., Font, J., Hagen, S., Metcalfe, J., and Smith, J. (2010), 'Collaborative doctoral education: university–industry partnerships for enhancing knowledge exchange', *Higher Education Policy*, Vol 23, No 4, pp 493–514.

Botterill, D., and Gale, T. (2006), 'Postgraduate and PhD education', in Airey, D., and Tribe, J., eds, *An International Handbook of Tourism Education*, Elsevier, Oxford, pp 469–482.

Bramwell, A., and Wolfe, D. A. (2008), 'Universities and regional economic development: the entrepreneurial University of Waterloo', *Research Policy*, Vol 37, No 8, pp 1175–1187.

Broström, A. (2012), 'Firms' rationales for interaction with research universities and the principles for public co-funding', *Journal of Technology Transfer,* Vol 37, No 3, pp 313–329.

Confederation of Swedish Enterprise (2012), *Högskolekvalitet 2012 – får studenter jobb efter examen?* Svenskt näringsliv, Stockholm.

Cooke, P., and Leydesdorff, L. (2006), 'Regional development in the knowledge-based economy: the construction of advantage', *Journal of Technology Transfer*, Vol 31, No 1, pp 5–15.

Damvad (2012), *Measuring the Economic Effects of Companies Collaborating with the University of Copenhagen*, Damvad, Copenhagen.

Davey, T., Baaken, T., Muros, V.G., and Meerman, A. (2011), 'The state of European university–business cooperation', *Final Report: Study on the Cooperation between Higher Education Institutions and Public and Private Organizations in Europe*, Science-to-Business Marketing Research Centre Germany, Muenster.

Denicolo, P. (2003), 'Assessing the PhD: a constructive view of criteria', *Quality Assurance in Education*, Vol 11, No 2, pp 84–91.

Ejermo, O. (2012), 'Universitet som drivkraft för tillväxt och utveckling' ['Universities as drivers for growth and

development'], Örebro University and Entrepreneurship Forum, Örebro.
Etzkowitz, H. (2003), 'Innovation in innovation: the Triple Helix of university–industry–government relations', *Social Science Information*, Vol 42, No 3, pp 293–337.
Etzkowitz, H. (2008), *The Triple Helix Model: University–Industry–Government Innovation in Action*, Routledge, London.
Etzkowitz, H. (2012), 'Triple Helix clusters: boundary permeability at university–industry–government interfaces as a regional innovation strategy', *Environment and Planning: Part C*, Vol 30, No 5, pp 766–779 .
Etzkowitz, H., and Klofsten, M. (2005), 'The innovating region: toward a theory of knowledge based regional development', *R&D Management*, Vol 35, No 3, pp 243–255.
Etzkowitz, H., and Leydesdorff, L. (2000), 'The dynamics of innovation: from national systems and "Mode 2" to a Triple Helix of university–industry–government relations', *Research Policy*, Vol 29, No 2, pp 109–123.
Florida, R. (2002), 'The economic geography of talent', *Annals of the Association of American Geographers*, Vol 92, No 4, pp 743–755.
Gunasekara, C. (2004), 'The third role of Australian universities in human capital formation', *Journal of Higher Education Policy and Management*, Vol 26, No 3, pp 329–343.
Huggins, R., and Strakova, L. (2012), 'Knowledge-based economic development in emerging regions: policy issues and implications in the Balkan Peninsula', *Regional Studies*, Vol 46, No 7, pp 961–975.
Karlsson, C., Johansson, B., Kobayashi, K., and Stough, R.R., eds (2014), *Knowledge, Innovation and Space*, Edward Elgar, Cheltenham.
Leydesdorff, L. (2013), 'Triple Helix of university–industry–government relations', in Carayannis, E.G., ed, *Encyclopedia of Creativity, Innovation, and Entrepreneurship,* Springer, New York.
Malfroy, J. (2011), 'The impact of university–industry research on doctoral programs and practices', *Studies in Higher Education*, Vol 36, No 5, pp 571–584.
Martin, R., and Sunley, P. (1998), 'Slow convergence? The new endogenous growth theory and regional development', *Economic Geography*, Vol 74, No 3, pp 201–227.
Metcalfe, J.S. (2006), 'Innovation, competition and enterprise: foundations for economic evolution in learning economies', in Hage, J., and Meeus, M.T.H., eds, *Innovation, Science and Institutional Change*, Oxford University Press, Oxford; also available as *CRIC Discussion Paper* No 71, CRIC, University of Manchester, Manchester.
Meyer, M., Grant, K., Morlacchi, P., and Weckowska, D. (2014), 'Triple Helix indicators as an emergent area of enquiry: a bibliometric perspective', *Scientometrics*, Vol 99, No 1, pp 151–174.
Mueller, P. (2006), 'Exploring the knowledge filter: how entrepreneurship and university–industry relationships drive economic growth', *Research Policy*, Vol 35, No 10, pp 1499–1508.
Nerad, M. (2010), 'Globalization and the internationalization of graduate education: a macro and micro view', *Canadian Journal of Higher Education*, Vol 40, No 1, pp 1–12.
Nuur, C., and Laestadius, S. (2010), 'Development in peripheral regions: case studies in Sweden', *European Urban and Regional Studies*, Vol 17, No 3, pp 293–307.
Nuur, C., Gustavsson, L., and Laestadius, S. (2009), 'Promoting regional innovation systems in a global context', *Industry and Innovation*, Vol 16, No 1, pp 123–139.
Nyquist, J.D. (2002), 'The PhD: a tapestry of change for the 21st century', *Change: The Magazine of Higher Learning*, Vol 34, No 6, pp 12–20.
Park, C. (2005), 'New variant PhD: the changing nature of the doctorate in the UK', *Journal of Higher Education Policy and Management*, Vol 27, No 2, pp 189–207.
Pham, B. (2000), 'Research at regional universities in Australia: visions and realisation', *Higher Education Management*, Vol 12, No 2, pp 117–130.
Power, D., and Malmberg, A. (2008), 'The contribution of universities to innovation and economic development: in what sense a regional problem?', *Cambridge Journal of Regions, Economy and Society,* Vol 1, No 2, pp 233–245.
Rosenberg, N., and Nelson, R.R. (1994), 'American universities and technical advance in industry', *Research Policy*, Vol 23, No 3, pp 323–348.
Schneider, P., and Sadowski, D. (2010), 'The impact of new public management instruments on PhD education', *Higher Education*, Vol 59, No 5, pp 543–565.
Smith, H.L., and Bagchi-Sen, S. (2010), 'Triple Helix and regional development: a perspective from Oxfordshire in the UK', *Technology Analysis and Strategic Management*, Vol 22, No 7, pp 805–818.
Stake, R.E. (1995), *The Art of Case Study Research*, Sage, Thousand Oaks, CA.
Stake, R.E. (2000), 'Case studies', in Denzin, N.K., and Lincoln, Y.S., eds, *Handbook of Qualitative Research,* 2nd Edition, Sage, Thousand Oaks, CA, pp 435–454.
Stimson, R.J., Stough, R., and Nijkamp, P., eds (2011), *Endogenous Regional Development: Perspectives, Measurement and Empirical Investigation*, Edward Elgar, Cheltenham.
Stough, R.R., Stimson, R.J., and Nijkamp, P. (2011), 'An endogenous perspective on regional development and growth', in Kourtit, K., Nijkamp, P., and Stough, R.R., eds, *Drivers of Innovation, Entrepreneurship and Regional Dynamics,* Springer, Berlin, pp 3–20.
Swann, J.P. (1988), *Academic Scientists and the Pharmaceutical Industry: Cooperative Research in Twentieth-Century America*, Johns Hopkins University Press, Baltimore, MD.
Thune, T. (2009), 'Doctoral students on the university–industry interface: a review of the literature', *Higher Education*, Vol 58, No 5, pp 637–651.
Thune, T. (2010), 'The training of "Triple Helix workers"? Doctoral students in university–industry–government collaborations', *Minerva*, Vol 48, No 4, pp 463–483.
Thune, T., Kyvik, S., Sörlin, S., Olsen, T. B., Vabø, A., and Tømte, C. (2012), *PhD Education in a Knowledge Society: An Evaluation of PhD Education in Norway,* NIFU, Oslo.
Todeva, E. (2013), 'Governance of innovation and intermediation in Triple Helix interactions', *Industry and Higher Education*, Vol 27, No 4, pp 263–278.
Tödtling, F. (2011), 'Endogenous approaches to local and regional development policy', in Pike, A., Rodrigues-Pose, A., and Tomaney, J., eds, *Handbook of Local and Regional Development*, Routledge, London, pp 333–343.
Wallgren, L., and Dahlgren, L.O. (2005), 'Doctoral education as social practice for knowledge development: conditions and demands encountered by industry PhD students', *Industry and Higher Education*, Vol 19, No 6, pp 433–443.
Webster, J. (2001), 'A principal component analysis of the US News and World Report tier rankings of colleges and universities', *Economics of Education Review*, Vol 20, No 3, pp 235–244.
Wohlin, C., Aurum, A., Rovegård, P., Tomaszewski, P., van Toorn, C., Winter, J., and Low, G. (2012), 'The success factors powering industry–academia collaboration', *IEEE Software*, Vol 29, No 2 pp 67–73.
Yin, R.K. (1993), *Applications of Case Study Research*, Sage, Thousand Oaks, CA.