—HIGHER—
EDUCATION
—POLICY—

Higher Education Policy, **2010**, **23**, (493–514)

www.palgrave-journals.com/hep/

Collaborative Doctoral Education: University-Industry Partnerships for Enhancing Knowledge Exchange

Lidia Borrell-Damian[a], Timothy Brown[b], Andrew Dearing[c,†], Josep Font[d], Stephen Hagen[e], Janet Metcalfe[f] and John Smith[a]

[a]European University Association, rue d'Egmont 13, Brussels 1000, Belgium.
[b]Mobile Communications Centre for Communication Systems Research, University of Surrey, Guildford, Surrey GU2 7XH, UK.
[c]European Industrial Research Management Association, 46 rue Lauriston, Paris 75016, France.
[d]Departament d'Enginyeria Química, ETSEQ, Universitat Rovira i Virgili, Av. Països Catalans 26, 43007 Tarragona, Catalonia, Spain.
[e]University of Wales, Caerleon Campus, Lodge Road, Caerleon, Newport, South Wales NP18 3QT, UK.
[f]Vitae, CRAC, Sheraton House, Castle Park, Cambridge CB3 0AX, UK.

This paper summarises the findings of the first stage of a pan-European study of collaborative doctoral training, which has examined programmes involving private sector partners. While studying for a doctorate has traditionally been seen as preparation for a job in academic teaching and research, for many candidates today (currently around 50%) this is a prelude to a wide range of careers. New programmes aim to offer the rigour of the conventional doctorate while giving more exposure to the nature of research in other sectors of the economy. Our analysis has revealed that these programmes are increasingly driven by the development of more strategic approaches to collaborative research and knowledge exchange. On the basis of the experiences reported by stakeholders, the paper suggests working practices and supporting policy measures that can address the (potentially conflicting) requirements for a high quality of education, sound research and adequate preparation for diverse career pathways. The paper also highlights the need for better data on, and more systematic tracking of, career pathways to improve confidence in the quality and suitability of all types of doctorate courses.
Higher Education Policy (2010) **23,** 493–514. doi:10.1057/hep.2010.20

Keywords: doctoral programmes; professional development; research utilisation

[†]Dr Andrew Dearing passed away in April 2010 shortly after the completion of this article. His co-authors wish to express their deep sadness at the loss of a colleague who was an accomplished practitioner in fostering excellence in research collaboration between universities and industry, and provided always a great inspiration to those who had the privilege to work with him.

Introduction: The Policy Context

The European university sector is undergoing many reforms as part of a broad social agenda designed to cement tertiary education, public and private sector research and innovation as foundations of modern knowledge-based societies. This agenda depends on enhancing the dissemination and adoption of advanced knowledge and skills, as well as their creation, and on developing what are often referred to as the research and innovation ecologies (Coombs and Georghiou, 2002; Dearing, 2007) to sustain these processes.

The political background is well known, particularly the headline (2000) Lisbon declaration in which EU Member States set themselves the goal of making the region the 'most competitive and dynamic knowledge-based economy in the world', and the subsequent (2002) Barcelona objective of achieving an aggregate research investment of 3% of GDP in support of this goal.

There are many initiatives underway to enhance the mobility and application of knowledge. The momentum for establishing a European Research Area, an initiative that aims to contribute to a better integration and organisation of Europe's scientific and technological area and create better overall framework conditions for research in Europe, is growing, and the need for accompanying changes in universities is reaffirmed regularly (European Commission, 1972, 2000, 2006). The new European Institute of Innovation and Technology is intended as a catalyst for change achieved through partnership with the aim of contributing towards industrial competitiveness and reinforcing Member States' innovation capacities by improving links between tertiary education and entrepreneurship. Many EU governments have legislated to give universities greater autonomy, and have liberalised and delegated the rights and responsibilities to manage the intellectual property rights (IPRs) resulting from university research. These steps are accompanied by critical assessments that link research funding to progress and publicly promote the achievements.

At the university level, there are increased levels of research collaboration with industry; greater involvement with local businesses and public institutions; the widespread establishment and operation of specialised professional units to handle the creation of spinout companies and licensing of intellectual property; development of science parks, incubator units and high-technology clusters near university campuses; and growing connections with the venture capital community. Among these complementary developments, the daily exchange of knowledge with firms, involving scholars and students, is widely felt to be the most important (Mowery, 2007; Hagen, 2008; Caraça *et al*., 2009).

In the private sector, the 20th century management mindset, which led to the growth of large, centrally managed, capital-intensive manufacturing companies, has also evolved. Current approaches emphasise flexibility and specialisation, thereby making relationships with complementary organisations more important.

One consequence is that many companies place more emphasis on working with the university sector as part of implementing approaches to innovation that are aligned with the 'Open Innovation' paradigm and (particularly for larger firms) designed to establish global research footprints (Chesbrough, 2003), and as a result the private sector also widely supports the university reform process. However, this way is not exempt of failures, barriers and concerns (Todtling *et al*., 2009). Some of the issues are mainly practical in nature (e.g. IPRs), while others are more fundamental (e.g. the nature, purpose and independence of university-based research).

Concerning IPR issues, considerable prior work exists to explain the underlying issues and how they can be resolved. This includes, for example, initiatives at grass-roots level (see the Handbook of Responsible Partnering www.responsible-partnering.org); at national level (see, e.g., the Lambert Model Agreements, www.innovation.gov.uk/lambertagreements/) and by the European Commission (see European Commission, 2008). The authors believe that more needs to be done to communicate these findings as part of tackling IPR matters, including their part in collaborative doctoral education.

Doctorate Training as Part of University Reform

Addressing the developments described in the introduction has extended universities' responsibilities and required them to diversify their funding base and manage new forms of partnership. There have also been consequences for their educational activities. In many countries, approaches to tertiary level education are in any case changing, for example, as a result of the Bologna Process and with the aim of creating a European Higher Education Area (EHEA) that is more attractive to students and faculty, facilitates mobility and better prepares students for their future careers and life as active citizens. Initially motivated by the need to elaborate compatible qualifications across national boundaries, supporting creativity and innovativeness is now recognised to be an important part of EHEA's purpose. Other research-intensive countries also report steps to adapt tertiary training to modern requirements (Harman, 2002; Kwiram, 2006; Akay, 2008).

In particular, the European Union is a major producer of doctoral graduates. One distinguishing feature of the European university system compared to the US is that a much higher proportion of universities are engaged in research, and hence in doctoral training. In 2005, the EU-27 produced some 100,000 doctorates. The region collectively awards around 15% more doctorates per capita than the US and 23% more than Japan, and the number is growing more rapidly (5% per annum) than in those countries, although more slowly than in China, which has rapidly increased its number of postgraduate students during this decade from a

very low base. The share of doctorate holders in the labour force in Germany and Switzerland is two to three times larger than in Australia, Canada and the United States (Chinese National Bureau of Statistics, 2006; OECD, 2007, 2008a, b).

It is now estimated that more than half of all doctoral candidates find their first employment outside academia. Some join established companies (a growing number preferring the small, science-led firms based around university campuses), government agencies and professions. Many of those who choose to remain within academia nonetheless find themselves working at its interface with other parts of society.

The development of collaborative doctoral programmes has accompanied these landscape changes, and a significant number of doctoral candidates in some countries are now being funded directly by industry or through government programmes that involve industrial participation. Examples include France, Denmark and the UK, where, as explained later, relevant government-led programmes to this effect have been in place for many years.

These trends have raised questions about the suitability of classical doctoral programmes; but at the same time there are also questions about the consequences of linking the doctoral qualification to industrial research priorities and funding; the merits of what are known as 'professional' or 'practice-based' doctorates; and the consistency and standards provided (Winter *et al*., 2000; Johnston and Murray, 2004; Neumann, 2005; Taylor, 2008; Fenge, 2009; Lee *et al*., 2009).

Outside the field of professional doctorates, doctoral courses generally remain organised around closely supervised individual research projects. The traditional course evolved to assist candidates' intellectual and personal development, predominantly according to the requirements of an academic career. This evolution continues today, for example many candidates take courses (and indeed may be required to take) that are intended to provide them with transferable career skills in areas such as intellectual property management, project management and other business activities. Some carry out the university-based components of major research contracts with industry. Many spend at least some time in a setting other than the home university. While learning the methods of academic research, many candidates are involved in a wider range of project types, are being prepared for careers that involve a broader set of research skills, and are gaining a greater understanding of how research findings are subsequently applied than hitherto.

The DOC-CAREERS Project: From Innovative Doctoral Training to Enhanced Career Opportunities

Despite the significance of the trends outlined above, there is only limited information on the overall qualities of current collaborative doctoral

programmes and of steps that can be taken to enhance programme value and candidates' subsequent employability. A primary purpose of the DOC-CAREERS project has been to obtain better insight into these points. In its first phase reported here, the focus was primarily on collaborations with large firms, in order to make recommendations arising from the analysis of collaborations with this specific type of companies that can assist programme development and feed into policy dialogue. It addressed the following points and their interconnections:

(i) the nature and extent of existing university and industry collaboration in doctoral programmes;
(ii) inter- and intra-sectoral mobility strategies for career development;
(iii) the development of transferable skills and competencies in doctoral programmes to enhance employability and career perspectives in private and public sectors;
(iv) the extent to which appropriate and systematic data collection at university level supports underpin programme development.

Note that it was not an objective to draw country-by-country comparisons, and data were not collected with this outcome in mind.

The DOC-CAREERS project was managed by two of this paper's authors (Lidia Borrell-Damian and John Smith), and a steering committee involving all authors planned the activities described in the text. Full details concerning methodologies, findings and analysis of case studies have been explained in a report published by the European University Association (EUA http://www.eua.be/fileadmin/user_upload/files/Publications/DOC-CAREERS.pdf). The present paper highlights some of the main findings and trends identified, and includes an additional discussion on emerging patterns.

Methodology

Preliminary information was gained by looking at the evolution of government-led collaborative Ph.D. programmes such as France's CIFRE (Convention Industrielle de Formation par la Recherche), the UK's CASE (initially known as Collaborative Awards for Science and Engineering, although the full name is now deprecated) and Denmark's Industrial Ph.D. programmes. The UK's CASE scheme began in the 1970s in order to provide universities with a way to set up individual courses connected to a specific industrial research interest outside the scope of departmental block grants. Today, all six of the UK research councils have adopted a diversified approach to collaborative programmes and several focus on centre-based schemes such as Doctoral Training Centres that have the capacity to develop a full range of desired skills

in chosen priority areas, and give a stronger role to companies (large and small) and national initiatives in defining the nature of the doctoral candidates' research. Alongside these government-led programmes, there are also a large number of direct university-industry initiatives, for which objectives and approaches are less well documented.

Input in DOC-CAREERS was obtained through (a) university case studies on doctoral programmes; (b) university case studies on tracking methodologies of doctoral holder careers; (c) consultation with industry; (d) consultation with doctoral candidate/holders and other stakeholders; (e) workshops (Figure 1). In total, DOC-CARERS received contributions from 82 organisations, including 33 universities, 31 enterprises and 18 other stakeholders from 19 European countries (http://www.eua.be/fileadmin/user_upload/files/Publications/DOC-CAREERS.pdf).

Primary contributions came from members of the EUA and the European Industrial Research Management Association (EIRMA), thereby obtaining extensive coverage from academic and medium to large enterprises operating throughout Europe. The aim was to collect first-hand experience from the full range of people concerned with the training, skills and employability of doctoral holders, across a wide geographical base within Europe. Four specific and extensive questionnaires were developed for: (i) universities (one

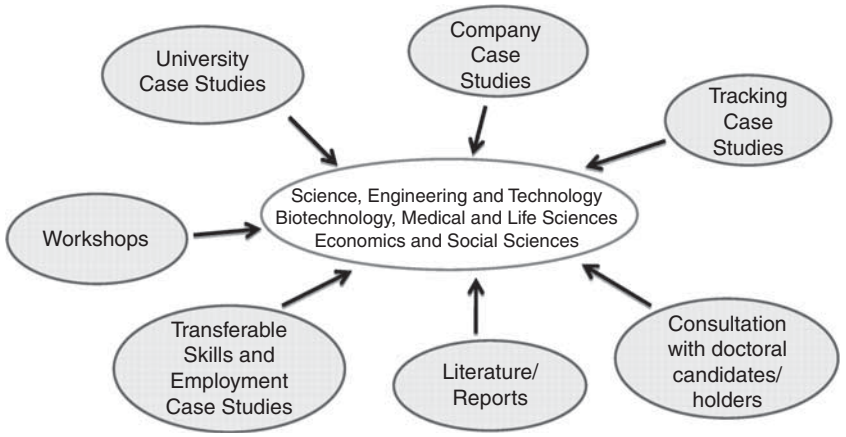

Figure 1. Schematic organisation of DOC-CAREERS project. Abbreviations: EIRMA, European Industrial Research Management Association; EURODOC, the European Council of doctoral candidates and young researchers.

for doctoral education by EUA — 40 closed and open-ended questions; (ii) methodologies for tracking of doctorate holder careers by UK GRAD Programme (now Vitae) — 27 closed and open-ended questions; (iii) companies by EIRMA — 44 closed and open-ended questions; (iv) doctoral candidates/holders by the European Council of Doctoral Candidates and Junior Researchers (EURODOC) — 25 open-ended questions.

Universities were invited to contribute with their case studies through calls for expressions of interest published on the EUA website. Responses were filtered according to the evidence of industrial involvement and disciplines involved, and to achieve geographical spread throughout Europe. Examples were sought covering three disciplinary fields: science, engineering and technology (SET); biotechnology, medical and life sciences (BML); and economics and social sciences (ESS). The text reports significant differences by attributing them to the respective field(s). Seventeen resulting case studies from 14 countries were used to identify initiatives, current practices and potential models of collaborative doctoral education (http://www.eua.be/fileadmin/user_upload/files/Publications/DOC-CAREERS.pdf).

In parallel, a group of 31 companies was selected, based on criteria that took account of a spread of innovation profiles, industrial sectors and geographical location. Interviews were held by telephone or by on-site visit with senior managers in these companies. The methodology for determining innovation profile was based on that reported in the working paper 'Indicators of Non-Technological Innovation' (OECD, 2007) DSTI/EAS/STP/NESTI (2007) 17. We informally scored 150 companies with active own R&D portfolios as being either active or not active on each of the innovation activities used in the fourth round of the Community Innovation Survey. These activities range from innovation in goods and in services, through intramural and external R&D to design, copyright and training. These scores were then consolidated into factors describing the emphasis of their innovation processes, which in turn provided scores in five clusters (market innovators; non-innovators; super-innovators; design-based development; and management innovators).

In addition to the input from doctorate candidates and holders provided by EURODOC, some of the university case studies included outcomes of internal surveys on tracking the professional careers of their doctorate candidates and holders.

Three workshops gathered a total of 92 representatives from 19 countries working in university or university networks, professional bodies, government bodies and corporations with strong research activities. The first workshop addressed alignment between universities and industry in what is understood as transferable skills. The second analysed existing university-industry collaboration in doctoral programmes, structural conditions and drivers, and the perceived value of mobility in enhancing employability. The third discussed the

main findings from the diversity of inputs to the project. To ensure reasonable validation, a high proportion of those invited to attend the final workshop did not take part in the earlier workshops.

Contributions on data tracking methodologies for doctoral graduates' careers were received from 11 institutions, including eight universities plus the European Molecular Biology Organisation, the UK's Higher Education Statistics Agency, which collects data from individual institutions and collates them nationally, and the OECD Careers of Doctorate Holders study (aimed at developing comparable national data sets leading to an internationally comparable system of indicators on careers and mobility of doctorate holders).

Analysis of the DOC-CAREERS Case Studies

The analysis of the university case studies, interviews conducted with enterprises, doctorate candidates/holders and other stakeholders focussed on the contexts, trends and strategies underlying the development of collaborative doctoral programmes and employment perspectives. A selection of the empirical findings are reported below as common trends and perspectives emerging through the myriad of particular initiatives, reasons, benefits, concerns and challenges stakeholders find when engaging in collaborative doctoral education.

On the basis of the case studies provided by universities, we term as 'Collaborative Doctoral Projects/Programmes' those doctoral theses/programmes carried out with interaction between a university, a company and a doctoral candidate. A distinctive characteristic is that experts from industry take part in the supervisory committee, officially or informally. Their participation can take several roles, but being in the supervisory committee is what effectively reflects the specific nature of the collaborative doctoral project.

Characteristics of Collaborative Doctoral Programmes

The data gathered confirmed a trend towards increasingly structured approaches to doctoral education involving industry in the last 10–15 years. The detailed contributions provided by universities and companies demonstrated several common features, described below and discussed in a later sector, which together provide a typology describing the structure of collaborative doctoral programmes. These can be characterised by the following parameters: (i) the level of institutional involvement; (ii) the type of coursework and placements that accompany the research; (iii) partners' roles; (iv) admission requirements; (v) the nature of the research carried out and who defines its objectives; (vi) formal agreement process; (vii) confidentiality and IPR; (viii) legal status of candidate; and (ix) supervisory procedures.

No single approach stands out as defining 'best practice', but some trends are clear, which for the most part agree with findings from recent country-centred studies (Kolmos *et al*., 2008).

(i) *Strategic level of engagement*: The submitted examples and interviews revealed a growing strategic engagement between companies and universities, measured in terms of the organisational levels involved. An underlying factor seems to be the emergence of sufficient experience and trust to justify developing high-quality, long-term research partnerships, which in turn allow the university and company to commit to providing the required infrastructures and resources. Such strategic partnerships sit alongside other, less formal, initiatives handled mainly by middle management. There was no evidence to suggest that the level of engagement adversely affects the outcome for the individual doctorate candidate.

(ii) *Coursework, skills development and structured placements*: Many doctoral programmes now involve coursework elements known as transferable skills. Discussion of these skills and their training proved to be controversial during the three workshops, but especially during the third one, where 17% of the participants came from the business sector. While there was general agreement that certain skills are important, there was less consensus on whether they could or should be provided as a structural element of doctoral education. Some company delegates expressed alarm that universities might feel competent to anticipate their needs without consultation. Regardless of the validity of such concerns, workshop participants agreed that it is also important to make more explicit the implicit (as well as the explicit) acquisition of skills during the doctoral period to employers, professors and to the doctorate candidate and holders.

We use the term 'structured placement' to define a period of time spent in industrial premises as an integral part of the candidate's education. The hard data provided in the university and company case studies highlighted the importance of structured placements, but revealed a wide range of practices in terms of duration, location, role of the company and role of the doctoral candidate in the company. Programmes in the fields of SET and BML tended to offer more structured placements than those in ESS. For government-driven initiatives, the placement may be mandatory; otherwise it may be agreed individually between the university and company. Candidates may become part of the company's research group or work individually using its facilities to support their research. Placements can be spent in one single period; be distributed throughout the project, or be daily, part-time, etc., depending on the project and sponsors' policies.

(iii) *Role of industrial partner*: In the cases analysed, the industrial contribution typically involved five main elements: supervision, funding, placements, data provider and network facilitator. Of these, supervisory activities played a key part in defining a programme as collaborative. Funding could be direct, in the form of the partial or full payroll of the candidate, or indirect, through provision of infrastructure, research material, access to industrial facilities and seminars, etc. Funding and legal status are explored in point (viii). Supervisory activities are discussed in point (ix). Many companies participating in the reported programmes allowed candidates to work with corporate data, within due disclosure policies. Highlighted by practitioners in all fields as a main motivation for working with industry, this was seen as particularly important in the case of ESS studies.

(iv) *Additional admission requirements*: In some of the cases studied, candidates wishing to pursue a collaborative programme had to fulfil additional requirements in addition to the university's policies for admission to doctoral education, which normally require an academic degree (normally Master). When a programme was industry-driven and a company hosted candidates as employees, the candidates may have had to go through additional interviews, follow company-standard recruitment procedures, accept different rights, for example in respect of ownership of IPRs they generate, or possess pre-existing professional experience. Particularly if the candidate is to spend significant time in the company or is seen as a potential employee, interpersonal skills and potential fitness for the company culture often become important.

(v) *Selection of research topic*: The doctoral research topic has to meet the needs and requirements of the university, company and individual doctoral candidate. The case studies showed that all combinations of topic selection exist:

- By the candidate, alone or in cooperation with the supervisor;
- By negotiation, taking account of the needs of the candidate, university and company;
- By negotiation between the university and company without involving the candidate;
- By the framework of a broad and pre-established research programme.

In approximately 60% of the cases studied, the topic was selected by negotiation between the university and company. In 35% the company decided exclusively and the candidate could suggest minor changes. In only 5% did the doctoral candidate take the lead, a practice favoured by some large companies that welcomed spontaneous applications.

(vi) *Formal agreement and conditions*: The contractual agreement established at the start of the project provides a sign of commitment and establishes

boundaries, resources and type of support that the partners commit to the project. Its main value lies in the discussion that precedes signature, increasing trust and clarity over objectives and mitigating risks such as disputes over IPRs and publication rights. Some of the university case studies provided extensive information on the content of the contracts that normally included:

- A description of the research project, its duration, committed resources and financial provisions;
- The rights and duties of each party: supervision of the candidate, monitoring of progress, reporting periods and deliverables, placement conditions, dedication, meeting arrangements, health insurance, compliance with standard procedures, etc.;
- Confidentiality issues, IP ownership and rights over outcomes with potential commercial use;
- Contingency plans in case of withdrawal from the project and other items such as liability clauses, general conduct of the research, etc.

Government-driven initiatives tended to mandate a contract at the beginning of the collaboration. Industry-driven or university-driven initiatives may have required a contract, but not necessarily one signed by all three parties. Some companies preferred a broad collaborative research contract with universities and left up to them the tasks of recruiting candidates and handling legal aspects. Contracts were more common in the fields of SET and BML. In the ESS field, the company's role was frequently that of funder and data provider, and a confidentiality agreement specifying the terms of use of data and name of the participant company may be sufficient. Currently, companies tend to have the greater interest in signing an agreement, typically to provide a sound basis for handling IPRs, should these arise.

It was found that normally there were contingency plans to ensure the completion of the doctoral thesis in case of a firm's eventual need for withdrawal from the project, due to change of research priorities, business strategy, crisis, etc. Although companies would generally try to fulfil the contract conditions, the company may also try to reorient the project, or the university may find other ways to secure funding until completion of the thesis.

(vii) *Confidentiality and intellectual property rights*: In general, the collaborative doctoral cases showed that there is an inherent tension between the candidate's and university's need to publish and the company's (and in many countries also the university's) need to secure possible future exploitation of results, especially in SET and BML fields. Most cases managed to resolve confidentiality and IPR issues successfully but some reported long delays (up to 2–3 years), especially when both partners

were working towards establishing a common understanding to cooperate in a long-term basis.

To avoid such problems, some universities and companies preferred that collaborative doctoral projects concentrate on areas of fundamental research, where issues of IPR and confidentiality are less likely to be significant. This is a good solution for companies with a long-term R&D strategy, but likely to be less appropriate for those with shorter-term interests. From our case studies, points that are normally considered in IPR agreements in collaborative doctoral projects include:

- The process for approving publications
- Whether to preserve the non-academic partner's anonymity
- How to protect rights to results with potential commercial application
- Who will retain or share IP ownership
- Whether rights to exploit IP will be exclusive to the participant firm
- Whether rights will be governed by (negotiable or non-negotiable) internal agreements or by national policies
- Whether to work only with partners with whom these questions have already been settled

One of the benefits of a more strategic engagement comes from having already worked through these issues.

(viii) *Legal status of the doctoral candidate*: Doctoral candidates' funding and legal status are intimately related. Government-driven programmes may grant employee, research fellow or student status. In industry-driven programmes in the fields of SET and BML, a company normally paid a high proportion of the candidate's salary, and may also have employed the candidate. In ESS, it was not uncommon for the candidate to be self-employed and have no formal status other than doctoral candidate. Candidates' legal status can be grouped in five general types:

- Fellowship/student of the university
- Fellowship of a public research funding body
- Employed by the university (teaching or professor assistantships, researcher)
- Employed by the industry or industry employee seconded in university
- Self-employed

Submissions emphasised the importance of sufficient legal cover to establish candidates' rights and duties, address health and safety issues, and protect authorship of research findings.

(ix) *Supervisory scheme*: As already noted, a key component of collaborative programmes is that an industry expert forms part of the supervisory committee, where the candidate's project is monitored and its quality ensured. Without such direct involvement, it is difficult to describe a project as providing a collaborative education. In the SET and BML fields, case

studies indicated that this joint approach is common. Supervisory committees normally include 1–2 university staff, 1–2 industry experts and sometimes a career development expert. Some companies have employees who hold part-time professorships, which provide ideal profiles for membership of supervisory committees. Nonetheless, the frequency of meetings of the joint supervisory team was found to be extremely diverse, from daily exchanges to once or twice a year, and depend on variables such as the nature of the research, the level of trust, physical distance to meet and agreed level of commitment. Reporting and assessment periods also varied from 6 months upwards, with 1–2 years being the most common period.

Data Collection for Tracking Doctoral Holders' Career Paths

One part of this project aimed to identify the role of systematic data collection at institutional level to provide the basis for the analysis of doctoral graduates' career paths. It analysed specifically:

- Types of data tracking systems in universities, resources needed and challenges associated with setting up the data collection;
- The uses, benefits and outcomes of data tracking by universities;
- The potential for wider application and transferability of the methodologies to other universities.

The motivations for the (limited number of) studies reported to us covered a wide range within two principal areas: providing input for the design and review of the structure and content of doctoral programmes and obtaining data on the career paths of doctorate graduates to inform other candidates of their career opportunities. Although the diversity of motivations, mechanisms and target audiences have precluded direct comparisons, analysis of the types of data collected produced some interesting themes.

Those surveys aimed at exploring respondents' experiences of doctoral programmes were most likely to ask about the experience of doctoral programme, the appropriateness of the doctoral training and degree for employment, and the skills and competencies developed through the doctorate. Those surveys aimed at understanding careers of doctorate graduates, and the labour markets were most likely to collect data on their current employment and level of satisfaction. Institutions collected this information to be able to inform doctoral candidates of their likely employment options and to ensure that their doctoral programmes support the development of their employability.

The reported benefits of career tracking studies and the information gathered included further exploration of the skills and competencies that

doctorate graduates require to inform programme curricula development, and hence attracting future doctoral candidates. Main challenges included the need to provide doctoral programmes that enhance the employability of doctoral graduates in all labour markets, for example, both academic and non-academic career paths. Institutions also highlighted the difficulty of building comparable data sets so they could benchmark their doctoral programmes in terms of how well they prepare doctoral candidates for employment, compared to other institutions.

Emerging Patterns

We bear in mind that the empirical findings reported here stem from interviews and materials of those who are already involved in university-industry partnerships. Such reporters may be more optimistic about the benefits than the average representative from industry or academia. Nonetheless, some overarching patterns emerged from the analysis of all contributions to DOC-CAREERS regarding changes in doctoral programme content, setting up collaborative doctoral projects and programmes, and the skills of doctoral holders valued in academic and non-academic post-doctoral careers. These concern the part that doctoral programmes play within the overall portfolio of relationships among companies and universities, and the characteristics of effective programmes that many components of traditional doctoral courses can transfer over directly to collaborative programmes, and the value and need for better data tracking.

Strategic engagement and fitness for purpose

This project has highlighted the extent to which collaborative doctoral education is increasingly been seen by the academic and business sectors as just one, although important, element of a much broader portfolio intended to cement durable relationships organised around research. The findings also suggest that relationships between research actors are widely reaching the level of maturity required to promote such relationships.

It is reasonable to suppose that the levels of an organisation that are engaged in collaborative doctoral programmes reflect both that organisation's degree of commitment to such activities and its strategic intent. In a university, this engagement (beyond the formal signature authorising a project) could lie at the level of a senior researcher, research group, department or school, or the whole institution. A wider engagement suggests that the university has established a plan that is motivating its researchers and leadership to develop contacts with industry, with doctoral projects being one tool supporting these contacts.

Similarly, in a company, a more strategic engagement generally accompanies a decision to implement a research strategy in which universities are seen to play a significant long-term role.

The data gathered also made clear that the traditional foundations of a doctorate, involving a structured and closely supervised research project and certification of the qualification by the university, remain valid for collaborative programmes. The added benefits of collaborative programmes come from candidates' exposure to, and understanding of, different priorities and ways of working in different research environments.

Doctoral candidates in general viewed their involvement in collaborative programmes very positively. Some universities had found that these programmes reduce the risk of candidates stepping out of the process to get a job when the applicability of their work becomes visible. However, candidates sometimes enjoy the business environment so much that they are distracted by other tasks and neglect their research. Dealing with several supervisors and handling requirements for different reporting systems provides challenges and adds complexity to the coursework. It can also lead to compromises in selecting and fixing the research topic, leaving no party entirely satisfied.

Effective programmes

The case studies confirmed that excellence in research is the primary hallmark of successful collaborative programmes. Such programmes build on academic and industrial strengths to achieve quality, and do not require compromises in respect of standards of education and research.

Next to the role of the industrial partner as part of the supervisory team, structured placements in industrial facilities are seen as one of the most important contributions offered to the doctoral candidate. Such placements contribute directly to the candidates' breadth of experience and to employers' subsequent perceptions of their employability. The exposure gained from using corporate facilities, participating in business meetings, and even having lunch in the staff canteen enables candidates to develop a better understanding of the problem and industrial culture, while fostering knowledge transfer in both directions. The opportunity to start building a network of contacts outside the academic environment is a valuable accompanying benefit. Even those who decide to pursue a university research career can benefit from an industrial placement.

Practitioners in all sectors and fields agreed that, independently of how well-organised a collaborative programme may be in formal terms, its success also depends on the quality of the personal component, the ability to work collaboratively to solve problems, achieve excellent performance, and establish good levels of mutual trust. Table 1 summarises these findings.

Table 1 Collaborative doctoral work — general points

Universities, businesses and doctoral candidates in common research grounds
Added values: • Quality of research: academic standards with strategic value for industry • Insight into both academic and non-academic organisations • Broadening employability perspectives for doctoral holders by learning to apply skills and knowledge acquired through research in industry (skills & knowledge transfer) • Reinforcing university-business cooperation: joint supervision, mutual access to academic and business networks, etc.
Outcomes: • Doctoral graduates with a better understanding of the industrial world • Doctoral graduates better prepared for employment outside academia • More and better links between university and industry
Concerns: • Excessive focus on non-academic activities • Limiting freedom for the development of break-through ideas • Conflict on publication rights, intellectual property rights • Supervisory scheme: communication issues, quality
Solutions: • Committing resources: material — access to necessary equipment; human — supervisors, doctoral candidate, others if necessary • Realistic expectations from all sides: project fitting into both academic and business research fields and strategies, awareness of the nature of the doctoral process, time-frames, needs, expected outcomes, work load, etc. • Formalisation of an agreement and flexibility to accommodate to unforeseen situations

Future skills and employability

Although the project revealed many areas of agreement, there were differences of opinion between companies, universities and doctoral candidates regarding candidates' skills and employability. It is clear that companies and universities have different expectations and look for different credentials.

Some universities reported no significant difference in the employability of doctoral graduates from both traditional and collaborative doctoral programmes, and others felt that collaborative schemes offer qualified benefits, such as for employment in research-oriented companies when there has been extensive interaction with industry throughout the development of the thesis. There were also some more negative opinions expressed, which reinforce the stereotype that industry is still seen as a secondary option by graduates with a more theoretical orientation, implying a belief that candidates who enrol in collaborative doctoral programmes do normally aim to pursue a career outside academia.

By contrast, companies unanimously reported that candidates who had participated in collaborative programmes were more employable and better prepared to develop successful academic and non-academic careers, because they had embedded business experience together with academic standards. Companies highlighted the 'bridging' nature of these doctorate holders, achieved through qualities such as an ability to communicate between the worlds of business and academia.

The dialogues demonstrated that private sector employers tend to look for professionals with both breadth and depth (also called 'T-shaped' individuals, referring to their ability to apply knowledge across situations, as well as the depth of their functional and technical skills (Leonard-Barton, 1995)), and that those universities that are used to working with industry are aware of the broad range of skills needed in the labour market.

In addition to skills naturally acquired through research, there is a group of competencies common to all fields that are likely to make a doctorate holder more attractive to business sector employers. These include communication, negotiation and management skills gained through dealing with the added complexity of the collaborative project, adaptability, the capacity to deal with complex problems and to engage in multidisciplinary work and, increasingly, the experience of working in international environments. This confirms the findings of previous studies (Kentish *et al*., 2006; Manathunga and Lant, 2006).

From the very limited evidence gathered in this project, those SMEs that employ doctorate holders tend to place a higher value on doctorate holders who have the 'soft skills' to complement their research capabilities at the moment of being employed.

The larger R&D-intensive companies explored here tended to value a combination of deep knowledge and broader competencies likely to equip the person to handle subsequent career challenges. Interviews with these companies confirmed that the doctorate holder is normally recruited as a researcher, but over the years will tend to move to other types of positions (vertical mobility) or from one discipline to another (horizontal mobility). Many find opportunities for career development that take them away from research at stages during their careers, perhaps returning later.

Figure 2 illustrates the general trends on vertical mobility found in this study: on average, 20% of those initially recruited as researchers have moved to other positions after 5–10 years of career in the company. The pattern of movement depends on the company, but the tendency is clear: project and line management are the likely future responsibilities of many who are initially recruited into industry as researchers. (Many Ph.D. candidates receive little guidance on this aspect of an industrial career while at university, and the move from research into more general management is often imagined to be a negative point.)

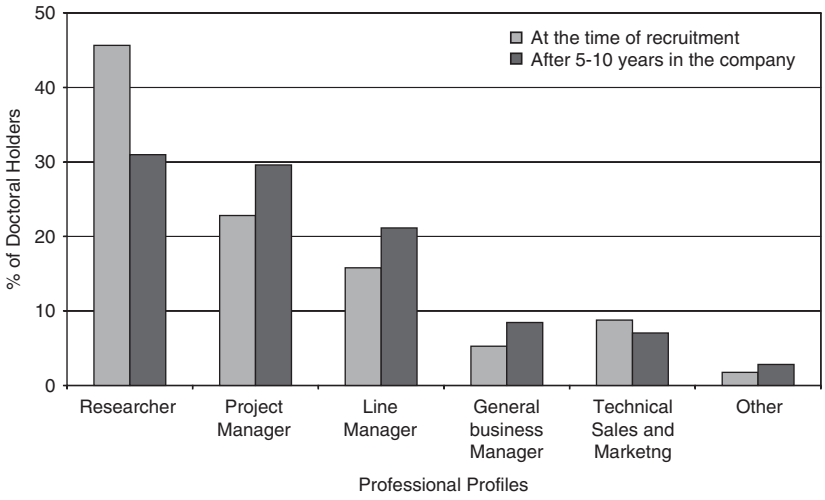

Figure 2. Changes in professional profiles following recruitment into industry.

Conclusions

The findings of this project reinforce the evidence of increasing collaboration between universities and firms, driven primarily by shared research interests, and suggest that this trend will not be short-lived. There was no evidence suggesting that academic standards need to be compromised in order to deal with the consequences. The findings also support the general statement that over half of doctoral holders can expect to be employed outside academia, often initially in research positions within the industrial manufacturing and service sectors, as well as in government and other public sector organisations, thereafter taking on a broader range of responsibilities beyond research.

The case studies demonstrated both the tangible and intangible benefits of collaborative doctoral programmes. For institutions and for society at large, these include promoting innovation, entrepreneurship and social responsibility, incorporating industrial input within university research, gaining awareness of industry's technological challenges, and contributing to sustainable funding for research. Those who followed a collaborative programme valued the expanded range of employment opportunities and understood that different positions require different sets of skills. When looking for employment, they took with them the reputation of a good collaborative scheme that funded the research and a greater commercial experience. However, they also reported some challenges compared to their peers in more traditional courses. These include difficulties such as balancing time between university and industry activities,

having to draft multiple reports with the same research outcomes, and possible constraints relating to pre-established boundaries for their research project.

Despite the broad range of industrial sectors and innovation profiles studied, the views offered on what companies expect from doctoral holders were quite uniform, as were perceptions of the strengths and weaknesses of doctorate holders in their first time in an industry environment. In general, companies are satisfied with the acquired knowledge and research skills of doctoral holders educated (by whatever route) in Europe, but point to the need for greater communication skills, improved awareness of intellectual property issues and better understanding of how businesses operate. While there was no evidence of a shortage of graduates qualified at doctoral level, submissions did reconfirm concerns about declining levels of interest in SET, and revealed that it is sometimes necessary to look outside Europe to find people with the required talents.

Universities and enterprises shared many common views on both opportunities and challenges that collaboration offers, from which we conclude that collaborative programmes cannot be viewed simplistically as a 'one-way street' favouring industrial interests. In this sense, the diagnosis at policy level of the situation is sound and barriers in Europe have been well identified. The experiences and views reflected in the DOC-CAREERS case studies also confirmed that the barriers can be overcome, but there are no 'one-size-fits-all solutions'. Successful approaches tend to incorporate local or regional cultural specificities as captured in the phrase 'the way we do things here'. The common feature is the gradual building of trust through professional standards of research collaboration, and this is sustained primarily through institutional commitment and systematic project management. Investing in developing the soft part of the relationship — proximity for easy opportunities of meeting, one-to-one dialogue, etc — is also clearly essential, and more platforms for dialogue need to be developed.

Resolving the challenges associated with establishing contracts and handling IPRs involves a combination of professional experience and mutual understanding. It is clearly important to differentiate between the doctoral process and its research outcomes. Specifically, discussions seem often to focus too strongly and too early on IPR ownership (or exclusive rights), when reasonable exploitation rights in a particular area may suffice and be easier to accommodate.

This evidence that collaborative doctoral education is seen as one element of establishing much broader portfolios of durable relationships highlights the complementary role of public policy. By recognising that the usual motivation for industrial participation in doctoral education is research excellence, policy initiatives can use this observation to facilitate the development of what we have referred to as stronger research and innovation ecologies, by addressing

wider structural issues outside the capacity of individual actors. The dialogue required to achieve durable relationships can be encouraged at many levels, but depends on the values promoted by political leadership, as well as firms and universities. From the evidence gathered, public funding and support are important, particularly for smaller firms that lack the resources needed to manage ongoing collaborations. Depending on national organisation, effective public support for these points may require better coordination between ministries and with funding bodies. Government funding can also lead to the necessary accountability and data collection needed to provide better organisational structure and enhance quality. Within limits, this will lead to better joint supervision and more satisfactory outcomes for all parties.

Better data tracking will permit a more structured exploration of the skills and competencies that doctorate graduates require, thereby informing programme curricula development and attracting future doctoral candidates. Currently, levels of activity are limited and there is little coordination of approach. (This also makes formal comparison of the effectiveness of different countries' government programmes more difficult.) Soft tools (e.g. use of alumni networks) can address some of the challenges, and progress could be made simply by sharing and adopting existing good practices or taking advantage of developments in data processing software. In order to promote more systematic data tracking, there may be a role for an organisation like the OECD (which, as noted, is already involved in developing an internationally comparable system of indicators on the careers and mobility of doctorate holders), in discussion with universities, to recommend appropriate methodologies and tools, similar to the Frascati and Oslo manuals for tracking R&D and innovation (OECD, 2002, 2005).

In summary, the evidence collected through the DOC-CAREERS case studies has demonstrated that universities and enterprises share many views on the opportunities, challenges and barriers associated with university-industry cooperation. Nonetheless, the case studies also showed how these barriers can be overcome. The basic terms of engagement are simple to state, but complex to build and manage: they entail adequate funding and resources; joint supervision; effective joint management reflecting common goals; and good performance in research leading to a degree gained according to established academic standards and not an expectation that one party should merely serve the other's objectives. There are no 'one-size-fits-all solutions' and successful approaches tend to incorporate local or regional cultural specificities, as captured in the phrase 'the way we do things here'. The importance is evident of making more explicit to students and employers that the creative skills acquired during research training (e.g., capacity to deal with complex problems, capacity to work well in international environments, thinking 'out of the box') can serve the knowledge society by developing new ways to

deal with problems and finding imaginative solutions in multiple working environments.

In order to assess the true importance of this diversity of approach, follow-up actions will be undertaken, which will study more specifically how universities work with their regional partners targeting sections of society other than large industry, including SMEs and public sector employers. Other areas for further review in the field of university-industry collaborative doctoral programmes include doctoral supervision and strategies for the recruitment and retention of doctoral candidates.

Acknowledgments

The authors acknowledge the European Commission contribution to this project sponsored under a Specific Support Action within the European Union's Sixth Framework Programme. The authors also acknowledge the support provided by Edwige Chassagneux, who performed much of the work associated with the corporate interviews while separately studying for her Ph.D. under the French CIFRE system.

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