Science, Technology and Innovation Studies

Leonid Gokhberg
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Laudeline Auriol *Editors*

The Science and Technology Labor Force

The Value of Doctorate Holders and Development of Professional Careers

Springer

Science, Technology and Innovation Studies

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Foreword

Over the last century, our societies have witnessed significant changes in their research systems and the way research is conducted. One dimension of this transformation is the specialisation and professionalisation in research and research training. In this context, the figure of the doctorate graduate—the "PhD"—has become increasingly prominent for it clearly epitomises this secular and relentless trend towards further specialisation in research.

The emergence of doctoral-level researchers reflects the expansion of higher education at postgraduate levels and the increasing role of universities as poles of research. This in turn has led to a policy debate in many countries over what is the appropriate model for training and supporting the career development of the next generation of researchers, those who will be in charge of providing and implementing solutions to today's major unsolved challenges. On the one hand, the traditional, almost apprentice-like, model has proved effective at building a cadre of highly motivated individuals with the expertise and know-how that is crucial for achieving the scientific excellence of academic institutions. On the other hand, there are concerns about this model's ability to train individuals for commercial research and broader innovation careers outside science or academia, especially as increasingly many researchers circulate between institutions and from one country to another.

Policy experimentation such as the expansion of doctoral programs, new forms of doctoral programs that are shorter in duration, the funding of postdoctoral training, as well as the provision of incentives to enterprises to temporarily engage or permanently employ PhDs have emerged. Robust evaluation of these policy initiatives is limited by the lack of sufficiently detailed data because general household surveys are not well suited to measuring small populations.

To address this gap, the OECD has teamed up with UNESCO and Eurostat to promote the systematic measurement of the careers of doctorate holders: the CDH project. This has helped elevate the dialogue about the data needed and the evidence required to better understand what incentives and motivations drive the supply and demand for skills for research and innovation, how they interact and which policies can improve the outcomes. This evidence is of value not only to policymakers but also to individuals who need information about their prospects when deciding whether to undertake the major commitment of starting a research career.

This volume constitutes an important step in this direction with valuable new evidence on this topic, drawing in part upon the CDH project and the network of researchers who have contributed to it. The various chapters provide different perspectives and insights on doctorate holders, their careers and labour market experiences, including some of the main outcomes of the latest wave of OECD work in this area.

Many of the contributors have generously participated in workshops and seminars organised by the OECD and partner organizations in the context of this project to whom I am thankful. Beyond the research findings, the formation of a global community of experts who focus on the intersection of data, methodology and policy analysis is a significant outcome. This book provides a valuable addition to the body of evidence and will hopefully trigger further research and discussion at a time when this is much needed.

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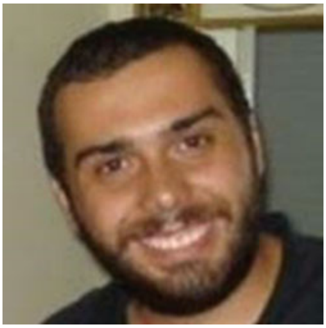

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Rethinking the Doctoral Degrees in the Changing Labor Market Context

1

Leonid Gokhberg, Natalia Shmatko, and Laudeline Auriol

Science, technology and innovation (STI) are important drivers of economic development and of social welfare at both national and global levels. It is widely recognized that the education and qualification of labor force is crucial for scientific achievements, technological breakthroughs and innovation excellence. Thus, ensuring the training and education of high quality labor force has become a central issue for policy makers. It used to be and it is still assumed that the population of researchers considerably drives scientific and innovation output. Lately, the inclusion of quantities of tertiary-level graduates and of new doctoral graduates in the development of composite national innovation indicators such as the Innovation Union Scoreboard (IUS) and the Global Innovation Index (GII) has become standard to assess the innovation capacities of the countries. In the first instance the basic number of tertiary-level graduates was considered a reasonable indicator, but the focus has also switched to the number of doctorate holders. These indicators have raised the attention of policy makers, and as a consequence, numerous initiatives in different countries at the global level have been implemented to increase the quantity of tertiary-level graduates and of doctorate holders (Dance 2013; Cyranoski et al. 2011). It is widely believed that the knowledge economy requires an ever larger quantity of highly qualified people. Yet, the latter is commonly associated with that holding academic degrees (Cyranoski et al. 2011), which in some way may be debatable. Vocational training for example does usually not involve tertiary education but remains a strongly targeted form of education for supplying specialists in both so-called 'blue collar' and 'white collar' positions. While it is important to understand the value of tertiary-level and

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doctorate degrees for research and innovation, which is the focus of this book, one should not lose sight of the overall competences that are needed for these activities.

Two parallel and concomitant phenomena have affected doctoral education over the past decades. Firstly, there has been a steady increase of doctoral students and graduates due to the massive expansion of higher education on the one hand and to the development of research and innovation activities on the other hand. This has occurred in a context of overall economic globalization that has fostered an increased integration of higher education and research systems. Secondly, many countries have implemented drastic reforms of their higher education systems, affecting the organization and content of university programs and in particular those leading to doctoral degrees, as we will see below. In Europe, for example, this has happened as part of the so-called Bologna process. How these two phenomena have influenced the supply, demand, as well as the career paths and skills of doctoral graduates is the object of this book. This is further introduced below and developed in the chapters of the book itself.

Doctoral education, as well as the number of doctoral students and doctoral degrees awarded, has indeed steadily increased over the last decades. The number of doctoral programs, in particular, has raised significantly in Europe and Asia. Not only traditional forms of doctoral education have expanded, but new forms of doctoral programs have appeared (Dance 2013). The increase of doctoral students and degrees delivered has been particularly remarkable in smaller European countries (e.g. Portugal) or new emerging economies (e.g. China) as a result of a deliberate policy or of favorable economic conditions and subsequent support to STI. In the US, an increasing scope of programs were designed to allow students with minority background to enter the doctoral education path (Powell 2013). In the most recent years, however, one reason for the increased numbers of doctoral students, can also, at least partially, be found in the event of the global economic crisis in 2008 which pushed students to enroll into doctoral programs as an alternative to choosing an immediate professional career in occupations outside academia (Monastersky 2009).

There has been some debate about the rising numbers of doctorates and the match between supply and demand of doctoral degrees on the labor market. In some instance, it has been argued that the number of doctorates significantly outweighed the actual demand for doctorates. This statement may not be generalized and depends on the countries, regions, time periods and fields of research. Nevertheless, it should be pointed out that the rapid increase of doctoral degrees has not been met by an equivalent increase of research and teaching jobs in the academic sector and even less so of stable (or tenure) positions. And while doctoral graduates increasingly find jobs in business, industrial research units often tend to recruit candidates with lower level degrees, e.g. bachelors or masters, and to train them on the job for the specific needs of companies.

It may also happen that individuals with specialized competence profiles generated by doctoral programs are perceived sometimes as over-qualified by potential employers. In such a case, doctorate holders find themselves trapped in a situation where they hold excellent competence profiles but where there is lack of demand for these competences.

Finally, there are also questions about the actual use and applicability of competences doctoral graduates have acquired as a result of their training and education. Doctorates are in the first instance prepared for academic research, but it has become evident that they increasingly require skills going beyond their core competencies, i.e. transferable skills (OECD 2012), not only for the labor market at large, but also for the academic world, which has undergone in-depth transformations over the last 20 years. One way of acquiring the complementary skills needed in academia has been through postdoctoral positions, many of which involve mobility abroad. International mobility has in these conditions become an important aspect of the doctoral labor market academic segment.

It is in this overall context that a major shift in doctoral training has occurred in Europe as well as in other countries. While doctoral education was traditionally based on a supervisor—PhD student relationship, the system has changed to more structured doctoral program training and education approaches. The former approach was focused on research only and usually involved a written PhD thesis, an associated defense and in some cases an oral examination of the subject area. Until the Bologna process became effective in Europe, the organization of doctoral education was mainly left to universities and within universities to faculties with respect to defining the requirements and specificities of doctoral programs. This made it difficult to assess and compare the quality of doctoral education between countries, not to say between individual institutions. Doctoral programs in European institutions nowadays include a broader range of training activities beyond just education in the field of the doctoral thesis. This is organized in a way in which doctoral students have more than one supervisor and learn from the different approaches and views conveyed by multiple supervisors (Dance 2013). The underlying assumption is that program-oriented doctoral training equips students with a broader skill set. A recent study by O'Carroll et al. (2012), for example, found that European doctorates enrolled in structured doctoral programs are more actively engaged in publications and conference presentations.

One important aim of structured programs is to shorten the actual time PhD students need to acquire their doctorate degree and prepare them for entering the labor market. However, there is at present no evidence about the fact that this model leads to an enhanced contribution of the doctoral students to scientific achievements and progress. At first sight one might argue that a shorter time frame for completing doctoral programs might have a negative impact on the quality and the novelty of doctoral students' dissertation theses but, at the same time, it seems obvious that as more doctoral students enter structured doctoral programs due to their shorter duration, the overall research output generated by their work is expected to grow. The balance to be found may well be one between quality and quantity.

The quality dimension may also be relevant when comparing doctoral studies based on a traditional doctoral thesis and those relying on a cumulative research work. The latter are more recent forms of doctoral output that are found in certain fields. They typically involve 2–3 peer reviewed journal articles which a doctoral student has to provide and a brief essay which elaborates on the overall research field and demonstrates how the journal articles fit in the overall research endeavor. Since journal articles are oftentimes authored by more than one researcher, the doctorate candidate has to show evidence that he contributed a significant share of work on the articles. Regardless the final output of doctoral studies, there are always documented results which contribute to the advancement of science. This aspect is frequently neglected in the discussion about the quantity of doctorates graduating from respective institutions which is probably due to the difficulties in assessing the contribution of these activities to the general advancement of knowledge and the impact on STI.

Whatever the breadth and depth of the research component of these new forms of doctoral degrees, an advantage of the structured programs is the underlying rationale to combine actual research work with the acquisition of a broader range of skills during the doctoral training. PhD students enrolled in structured programs frequently have to take additional courses and engage in teaching as well. Course work at the doctoral level is commonly organized across departments, sometimes even across scientific disciplines, which also offers doctoral students an access to networks and an insight into approaches followed by colleagues in complementary but still different fields. Hence doctoral students from structured programs are thought to be well prepared for interdisciplinary work. This combination of research strength and of other complementary skills is expected to better prepare doctoral students for the labor market. In the end, doctorate holders should be more qualified and equipped with a broader set of competences which are likely to offer them a broad range of employment opportunities in the labor market (Cyranoski et al. 2011).

One approach to match doctoral education with the actual demand on the labor market has also been the development of practice-oriented doctoral courses. These so-called professional programs combine research and practical experience on the job. Among these, industrial doctoral programs are increasingly common in many countries (Ori 2013; Schiermeier 2012). These programs are a means of involving industrial researchers in basic science by assigning research themes which are still at the early (exploratory) stage but for which potential forms of application are known and predictable. This form of doctoral programs is also understood as a way to align industry and science interests and leverage the respective competences.

To summarize, increased efforts for reforming the training of doctoral graduates have at the same time led to a rapidly growing supply of doctorates and a better provision of the skills needed for employment. Nevertheless, the labor market demand for doctorate holders has not grown at a similar pace, whether from the national science systems, from industry or from other potential employers. This phenomenon is currently observed in many countries. There is a more balanced supply-and-demand situation in emerging and transition countries which offer better potential for doctorate holders to get positions on the labor market. This however requires a more flexible and mobile behavior pattern from the side of doctorate holders and increased openness from that of the hosting countries and institutions.

This book attempts to give an overview of the different conditions affecting the training and employment of doctorate holders, some of which have been briefly introduced above. The studies represented in this volume have been strongly backed by various international and national empirical studies of both statistical and sociological nature.

The Part I of the book looks at the general characteristics of the labor market for doctorate holders addressing policy questions linked to the training of doctorates and their employment pattern, methodological issues with regards to tracking the careers of doctorate holders, and discussing data and information needs as well as respective mobility trends and labor market outcomes. *Barbara Kehm* and *Ulrich Teichler* describe the influence of the policy framework on the links between doctoral education and labor market in Europe. The chapter introduces a discussion on the destinations of doctorate holders and explains what the implications of multiple career paths are. *Laudeline Auriol* highlights the specific role played by doctorate holders among tertiary-level graduates. She notes that there is a significant gap in tracking and assessing the career paths of doctorate holders and describes a new internationally recognized approach to address this gap—namely the so-called 'Careers of Doctorate Holders' (CDH) project initiated jointly by the OECD, Eurostat, and UNESCO Institute of Statistics.

Laudeline Auriol, Toshiyuki 'Max' Misu and *Fernando Galindo-Rueda* provide analytical evidence of a labor market premium for doctorates in OECD countries and show that women and younger doctoral graduates fare relatively worse in terms of employment rates although less so than for lower degree holders. They demonstrate that academic positions of doctorates are increasingly fixed term in academia but more frequently permanent outside the academic world. Furthermore, they find evidence that mobility from the business sector to the higher education sector is greater than the other way around.

In the Part II, the employment and mobility of doctorate holders in the US, Belgium, Russia, Spain and Portugal are addressed using the CDH harmonized data. The chapter authors provide an in depth analysis of the career patterns of PhD holders in their respective countries taking into account the nation's specific framework conditions. Steven Proudfoot and Thomas B. Hoffer focus on the stock and flows of doctoral labor force in the US, Karl Boosten and André Spithoven—on pecuniary and scientific motives as drivers of Belgian PhD careers, Natalia Shmatko and Yurij Katchanov—on the mobility of Russian doctorate holders, Laura Cruz-Castro, Koen Jonkers and Luis Sanz-Menéndez—on international mobility of doctorates in Spain, Joana Mendonça and Joana Duarte—on PhDs career paths for Portugal.

Steven Proudfoot and Thomas B. Hoffer give an overview of the science, engineering and health doctoral population in the US showing their high level employment participation, as well as the increased representation of women and of non-US citizens. There is clear evidence of a decline in the availability of tenure-track positions in academia, and demonstrate the existence of alternative research careers opportunities in businesses.

Karl Boosten and *André Spithoven* investigate the wages earned by PhD holders and their choice for research positions as drivers of their careers. They note striking divergence across sectors of employment, gender, age, and type of contract. The Belgian case suggests that a research career in higher education has a significant effect on salary which appears not to be the case in industry.

Natalia Shmatko and *Yurij Katchanov* explore the role of different motivations, experiences, professional changes and other social phenomena in decision-making processes concerning career trajectories and the impact of mobility on growing researchers' scientific capital. They propose a conceptual model of scientists' social mobility.

The impact of Spanish doctorates' experiences with international mobility on their potential engagement in research positions and the likelihood of experienced mobile doctorates to get permanent employment are investigated by *Laura Cruz-Castro, Koen Jonkers* and *Luis Sanz-Menéndez*.

Joana Duarte and *Joana Mendonça* study what determines different employment patterns for PhD holders in Portugal and a few other European countries. They analyse doctorates' integration into research careers as well as their professional mobility and the factors affecting their earnings.

Human resources in science and technology and their professional careers are the focus of the Part III. The chapters in this Part, unlike those in the previous one, are mostly based on nation-specific surveys. Julien Calmand describes the transition of PhD holders from school to work in France, while Leonid Gokhberg, Tatiana Kuznetsova and Galina Kitova address professional values, remuneration and attitudes to science policy by Russian scientists. Ellen Pierce and Janet Metcalfe discuss approaches to realizing the potential of researchers in the United Kingdom, and Toshiyuki Misu and Akira Horoiwa analyse the domestic and internal destinations of Japan's doctorate holders. Adriana Bin, Sergio Salles-Filho, Fernando A. B. Colugnati, and Fábio Rocha Campos conclude the Part with an interesting analysis of developing the human potential base in Brazil.

Julien Calmand notes that young PhD holders in France encounter employment difficulties short after graduation. He argues that doctoral graduates possess a strong research background which is not fully recognized on the segment of the labor market outside the academic world and also that doctorates are in competition with other graduates at Masters' level education.

Leonid Gokhberg, Tatiana Kuznetsova and *Galina Kitova* complement this analysis with an in depth look into the mid-term prospects of Russian R&D personnel with a special emphasis on motivation and productivity and on the system of their professional values and career preferences.

Ellen Pearce and *Janet Metcalfe* document how doctoral students in the UK can benefit from government measures to enhance their skills and career promotion. They provide a comprehensive picture of the role of dedicated training and development of doctorates for their employability.

Toshiyuki Misu and *Akira Horoiwa* elaborate on the international mobility of Japanese doctorates and characterize their role in the domestic and global labor market.

Adriana Bin, Sergio Salles-Filho, Fernando A. B. Colugnati and Fábio Rocha Campos look at the special characteristics of an emerging economy and how advanced human resource capabilities are cultivated in Brazil. Their work also estimates the economic and social impacts resulting from the development of these special competences.

The concluding chapter of this book by *Dirk Meissner, Leonid Gokhberg* and *Natalia Shmatko* highlights the value of doctorates for innovation and proposes recommendations for STI policy making. It provides insights on the nature of scientific work by doctoral students and challenges the repeated call for increasing the number of doctorate holders in many countries.

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References

Cyranoski D, Gilbert N, Ledford H, Nayar A, Yahia M (2011) The world is producing more PhDs than ever before. Is it time to stop? Nature 472:276–279. doi:10.1038/472276a

Dance A (2013) Graduate students: structured study. Nature 493:259–261. doi:10.1038/nj7431-259a

Monastersky R (2009) The lure of the lab. Nature 457:642–643. doi:10.1038/457642a

O'Carroll C et al (2012) The PhD in Europe: developing a system of doctoral training that will increase the internationalisation of universities. In: Curaj A, Scott P, Vlasceanu L, Wilson L (eds) European higher education at the crossroads. Springer, Dordrecht, pp 461–484

OECD (2012) Transferable skills training for researchers: supporting career development and research. http://www.oecd.org/science/transferableskills.htm

Ori M (2013) The rise of industrial PhDs. University World News 300: 13 December 2013

Powell K (2013) Higher education: on the lookout for true grit. Nature 504:471–473, doi: http://dx.doi.org/10.1038/nj7480-471a

Schiermeier Q (2012) Education: outside the box. Nature 482:557–559. doi:10.1038/nj7386-557a

Part I

The International Value of Doctorate Degrees on the Labor Market

Doctoral Education and Labor Market: Policy Questions and Data Needs

2

Barbara M. Kehm and Ulrich Teichler

2.1 Introduction

In this chapter the larger policy framework that influences the relationships between doctoral education and labor market policy in Europe is described. In the first section, the traditions of doctoral education prevalent in continental Europe are contrasted to the US model of graduate education and a brief account is provided about the international (OECD) debate about the future of doctoral education. This is followed by an analysis of the implications of higher education expansion for doctoral education and training as numbers increased and the production of doctorates no longer exclusively served for the reproduction of academic staff. A third part develops a typology of destinations of doctoral degree holders followed by an analysis of the increasing diversification of the types of doctoral degrees of which altogether nine different ones were found. A major implication of this diversification is the distinction between research doctorates and professional doctorates, the latter being geared towards the transition into non-academic labor markets. A further part discusses the extended policy field in which a doctoral education is no longer an exclusively academic affair but is increasingly managed at the institutional level, embedded in national regulations and performance incentives as well as targeted by policies of supra-national actors, e.g. the European Commission, OECD or UNESCO. Doctoral degree holders have currently become a valuable resource in knowledge societies and economies. In addition, future policy and data needs are identified. The conclusions point out that although recruitment patterns and career

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progress for early career researchers in academia have become more standardised, they continue to be influenced by a number of other factors which contribute to the considerable complexity of the relationships between a doctoral education and academic as well as non-academic labor markets.

2.2 Traditions of Doctoral Education and Training

In the international debates about the character of doctoral education and training, the contrast between the German tradition and the tradition that has evolved in the United States is most often taken as a starting point. The German model, based on Humboldtian principles, understood students as learners to be confronted with the logic of research from the beginning of their studies and nurtured young academics through close relationships with a 'doctor father' or 'doctor mother'. In this model doctoral candidates were not understood as students any longer but as junior academics often in a salaried position as research assistants. The model is often referred to as the 'master-apprentice model'. The US-American model, though claiming to be based on Humboldtian principles as well, is clearly distinct from the German one in that it puts a greater emphasis on teaching and nurtures doctoral students in the framework of organized and structured programs within graduate schools (for this and the following see Teichler 2014).

The contrast between the two models is evident in the actual discussions that have gained momentum since the 1980s when the OECD identified doctoral education and training as a key issue of higher education and research policy (see Blume and Amsterdamska 1987). In this context the concepts of 'knowledge society' and 'knowledge economy' became popular in the 1990s implying the notion that the future of modern societies will depend more strongly than in the past on research and that countries might lose out if they cannot achieve the highest level of research. Attention increased to the visible signs of research quality in the USA as well as to the fact that large numbers of doctoral candidates from all over the world intended to have their doctoral training at US research universities. Consequently the policy discourse stimulated by the OECD in the 1980s was based by and large on a shared assumption that graduate schools in the United States could become role models for universities in other economically advanced countries (see Rhoades 1991; Gumport 1992).

However, looking more closely at the debates in Europe and the OECD countries in the 1980s and 1990s one could argue that many countries were trying to find improved ways of doctoral education and training by adapting elements of the US model. Doctoral education in the US was often portrayed as a 'success story' without any reference to debates about its strengths and weaknesses (but see, for example, Nerad 2004). As a consequence implementing the US model was seen as (1) providing a better quality of research training, (2) getting useful ideas for the training of researchers, (3) designing and implementing a more comprehensive training for the professional role of academics, and (4) developing doctoral education and training programs that were valuable for those who eventually would neither be academics nor researchers in other institutions.

The international debate on the future of doctoral education has intensified and become more sophisticated over the past 20 years. The strengths and weaknesses of a highly institutionalised and programmed approach versus an individualised apprenticeship approach have played a substantial role in this debate. In addition, however, many other issues were on the agenda as well, such as the distinct types of doctorates, the range of competences to be acquired during the doctoral phase beyond the ability to conduct research, and the relationship between training and productive academic work in this phase (see Kehm 2009). The extent of the diversity of views is not only related to the individual insights and preferences of the actors in this debate but also reflects the different conditions of national higher education and research systems and their societal contexts. The different views within countries and the different dominant realities across countries can be examined in seven major dimensions:

1. The extent of higher education expansion.
2. The extent and modes of diversification of the higher education and research systems.
3. The quantity of doctoral degrees as well as the academic and non-academic destinations of doctoral degree holders.
4. The role of the doctoral phase in the overall education, training and career development of academics.
5. The role of doctoral training in the context of overall training and career development for those persons who eventually become professionally active outside academia.
6. The overall situation and role of junior academics.
7. The changing views of desirable competencies and job roles of academics.

These dimensions became visible in various studies aiming to understand the situation of doctoral education and training in the wider context of higher education and its societal functions and from a comparative point of view. They were already evident in a study on the notions of research in graduate education coordinated by Clark (1993, 1994), in a review undertaken in the first years of the twenty-first century on "doctoral studies and qualifications" in Europe and the United States initiated by the European Centre for Higher Education (CEPES) of UNESCO (Sadlak 2004; see notably Kehm 2004), and in publications of a "global network" of researchers analysing "changes in doctoral education worldwide" and a possible trend "towards a global PhD" (Nerad and Heggelund 2008; see also Kehm 2012). Also helpful in this respect are the proceedings of a conference organised by the Academia Europaea on the "formative years of scholars" (Teichler 2006) and by UNESCO (UNESCO Forum on Higher Education, Research and Knowledge 2008). Two issues stand out in most of these reports also supported by the implications of the European Bologna Process for doctoral education and training. First, the need to shape and possibly reconfigure pathways to an academic career during the postdoc phase. Second, the need to provide doctoral students with skills and competences needed in non-academic labor markets. We will come back to these issues.

In sum, there is a variety of experiences in economically advanced countries based on past models of doctoral education and training and there is a variety of new challenges that call for new solutions. In the following we will address some of the elements for future developments of doctoral education and training that are similar across countries as well as other elements where substantial differences between countries can be observed.

2.3 Expansion of Higher Education and Its Implications for Doctoral Education and Training

The international debates on possible improvements of doctoral education and training tend to refer to the expansion of higher education as a major factor. Concurrently with this expansion, we also note the growing size of the academic and research system.

Irrespective of quantitative variations of higher education expansion—more than 50 % of an age cohort studying in higher education in many economically advanced countries, clearly less than that in most other countries, the OECD average being 50 %—and irrespective of the time at which expansion occurred—in the 1950s and 1960s in the USA, in the 1970s and 1980s in Europe, and more recently in many other countries—the conventional wisdom of expert debates in economically advanced countries has been rather similar. First, it is often pointed out that students and graduates have become more diverse in terms of their talents, motives and job prospects as higher education expanded (see Huisman et al. 2007; Teichler 2008). Therefore these students might be better served by an increased diversity of higher education institutions and programs. Second, higher education might have expanded to a lesser extent if the need for extending and replenishing teaching and research staff had been the major driving force for this trend. But this is not the case.

The rates of doctoral degrees awarded had been below 1 % in all countries for many years and were not seen as an issue in the general debate on higher education. For example, the chapters on the United States, the United Kingdom, France, and Switzerland in the first major international encyclopaedia for higher education (Clark and Neave 1992) did not provide any information about the number of doctoral candidates or the number of doctoral degrees awarded. Only in recent years has the expansion of doctoral degrees been referred to in the general discourse on the quantitative and structural developments of higher education. An average of 5 % annual growth in doctoral degrees across OECD countries was reported for the first decade of the twenty-first century, raising the rate of doctoral degrees among the respective age group from less than 1 % on average in 2000 to 1.6 % in 2010 (OECD 2012). Actually, the rates of doctoral degrees and similar advanced degrees have varied substantially by country over the decades and continue to vary more substantially now than the rates of bachelor's and master's degrees together. According to 2010 OECD data, the highest doctoral degree rates can be found in Switzerland (3.6 %), Slovakia (3.2 %) and Germany (2.6 %) as compared to the OECD average of 1.6 % (with 1.6 % in the United States, 1.1 % in Japan, and only 0.5 % in Poland). Interestingly, the proportion of foreigners awarded a doctoral degree was about one fifth across all economically advanced countries. This proportion is higher in Switzerland and the United States where more than two fifths were foreigners. In Germany, the figure is about one tenth in recent years.

Comparative rates of doctoral degrees must be regarded with caution because the figures presented in official national statistics as well as in the statistics of UNESCO, OECD and other supra-national agencies include only academic doctoral degrees in the United States (i.e., not professional degrees) but as a rule all doctoral degrees (including professional ones) in most other countries.

To summarise, the data and the respective discourse suggest that the expansion of doctoral education and training certainly has been affected by the overall expansion of student enrolment and by the respective need for an increase in academic staff in higher education. However, the expansion of doctoral education and training did not closely follow the patterns of overall student enrolment across countries, a finding that suggests that there are other factors at play than merely the reproduction of the academic profession. This will be discussed in the following section.

2.4 Destinations of Doctoral Degree Holders

Many factors might contribute to the large variations in the rates of doctoral degree awards in the respective age group across countries. Thus, a closer look at the role of doctoral education and training for various occupations is necessary. Generally, it is taken for granted that doctoral education all over the world works for the reproduction of the academic profession. However, in many economically advanced countries, more doctoral degree holders are produced annually in the meantime than are needed in academia and publicly funded research institutes.

However, because the categories employed and figures presented vary in national statistics, international educational statistics, and international research statistics it is not possible to present a reliable comparative picture of the various professional careers of doctoral degree holders outside academia. Reflecting about the strengths and weaknesses of available statistics we can attempt to establish a classification system concerning job destinations of doctoral degree holders which consists of the following six categories:

1. Members of the academic profession in charge of teaching and research at higher education institutions.
2. Researchers at public or not-for-profit research institutes.
3. People in industry and commerce whose professional functions include major components of research and development.

4. Persons outside the aforementioned job roles whose tasks include significant research or research-like components and/or require in-depth knowledge of research processes and findings, e.g. new higher education professionals active in quality management or research support at universities, sales managers of pharmaceutical products, or key administrative staff members of a professional association.
5. Persons professionally active without any visible research or research-like elements in their work but profiting from holding a doctoral degree as a higher level of educational achievement or through the symbolic power of the credential.
6. A residual group of individuals holding a doctoral degree and being professionally active but without any sign that their degree is professionally relevant in any respect.

As indicated above, in many economically advanced countries the number of doctoral degree holders has increased over the years more substantially than the number of academic positions in higher education institutions or research institutes. Occasionally, this disparity is depicted as an "over-supply" of doctoral degree holders. However, the employment of doctoral degree holders in non-academic sectors of the economy is increasingly seen as a desirable development on the way towards a 'knowledge society' or a 'knowledge economy'. Of course, this requires the non-academic labor markets to be open for doctoral degree holders which is not the case in all European countries (for example, not in Poland, not in Italy).

2.5 Diversification of Types of Doctoral Degrees

Over the years, the growth in the number of doctoral degrees awarded has elicited debates as to whether the establishment of different types of doctorates would be an appropriate response to the current situation. Based on a synthesis of the literature in the first decade of the twenty-first century, Kehm (2012) has identified nine types of doctorates which are awarded in all, some or just a single European country. These will be briefly described in the following paragraphs.

2.5.1 The Research Doctorate

For the research doctorate the dissertation is central and expected to be an original contribution to the knowledge base of a discipline or a research domain. Independent of the fact whether the degree (or title) is acquired within the framework of a structured program including course work or in the framework of a master-apprentice relationship, the research doctorate as a rule is an entrance ticket to the academic profession, which—by being responsible for the training—at the same time also has a gatekeeper function. Using the example of six disciplines, Golde and Walker (2006) have characterised the main purpose of doctoral education in the research doctorate as developing students to be “stewards of the discipline”. The goal of such training is a scientific or scholarly ideal type characterised as someone “who can imaginatively generate new knowledge, critically conserve valuable and useful ideas, and responsibly transform those understandings through writing, teaching and application. A steward is someone to whom the vigor, quality, and integrity of the field can be entrusted” (Golde and Walker 2006: 5). This rather normative image contrasts starkly with the image generated by Slaughter and Leslie (2000) of the successful academic as a “capitalist entrepreneur” who has recognised the demands and challenges of market orientation, competition and globalisation in the emerging knowledge societies and knows how to draw advantages from these developments.

2.5.2 The Taught Doctorate

By definition, the taught doctorate consists of a substantial proportion of course work. Typically there will be a fixed curriculum and learning outcomes will be graded and weighted for the final grade. As in the research doctorate, students are supposed to contribute to the generation of new knowledge but they do this in the framework of a research project, the results of which are summarised in a project report. The report is presented in the framework of an oral examination and is graded as well. In contrast to the two-phase doctorate in the United States (course work first, then research and writing of thesis), the course work of the taught doctorate is spread over the whole period of degree training (predominantly offered in the United Kingdom). The oral examination and the grade of the research project report are regarded as an equivalent to a dissertation and its defence.

2.5.3 PhD by Published Work

The model of the PhD by published work has been known in Germany since the nineteenth century (it is called “cumulative dissertation”). From there it spread to other parts of the world, mainly the United States but also to Belgium, the Netherlands and Sweden. When considered more closely, the British model of the PhD by published work differs to some extent from the German model of a “cumulative dissertation”. Both models are basically characterised by combining several articles which have appeared in peer reviewed scholarly or scientific journals into a book and providing them with a coherent framework. But while this option is open for many candidates in Germany, the PhD by published work is awarded in the United Kingdom almost exclusively to members or alumni of the university awarding the degree (cf. Green and Powell 2005: 72).

This model has frequently been criticised for:

- its lack of consistency and weak demarcation to other forms of doctorates,
- differences in the definition of what constitutes a publication and which timeframe should be taken into account,
- its threat to undermine other forms of doctoral education,
- the difficulty in allowing for adequate supervision.

Furthermore, in this model of the doctorate it is predominantly a product that is evaluated and graded and not the process of getting the degree itself. Therefore, most countries which provide this opportunity have regulations in place that determine the character and the content of the dissertation and possibly also the question about the form in which a program of additional studies has to be taken (cf. Green and Powell 2005: 71).

2.5.4 The Professional Doctorate

A number of European countries have by now picked up the British trend to explicitly distinguish between a research doctorate and a professional doctorate. The professional doctorate is not awarded in all disciplines but restricted to subjects like business administration, medicine and health care, education, engineering, social work, etc., i.e. to subjects which have a relatively demarcated field of professional practice. In professional doctorates, the title usually includes an indication of the professional field (e.g. DBA or EdD). Several publications have appeared in recent years on the professional doctorate (cf. Bourner et al. 2000; Park 2005; Green and Powell 2005). To some extent this seems to be related to the fact that in academic circles the professional doctorate is often looked down upon as a second-class doctorate, so pressure for legitimation increased.

The professional doctorate is defined as a program of advanced studies which—apart from fulfilling university criteria for the award of the degree—is geared towards satisfying a particular demand from a professional group outside the university and towards developing research skills needed within a professional context (Bourner et al. 2000: 219). In the United Kingdom, professional doctorates are typically taken up by people who are pursuing a professional career and are employed. Therefore, professional doctorates are frequently offered as part-time programs and usually require several years of professional experience. Tuition fees are often covered fully or in part by the employer. The target group wants to gain the degree in order to be eligible for promotion in their professional field. Consequently the research work carried out for the dissertation is regarded less as a contribution to the knowledge base of a discipline and more as a contribution to the development of a professional field. The dissertation then has a focus on the generation of new but more applied knowledge and the topic is often generated from the respective professional practice. In some areas, e.g., in engineering, the dissertation can also have the form of a larger or a series of smaller projects which are carried out in the framework of actual professional practice.

Apart from aspects of the subject or discipline, the course work involves training in research and research methods, with which problems in professional practice can be solved and it also involves a familiarisation with research results and their utilisation in or relevance for professional practice. There is also an emphasis on career management skills. Course work is usually graded separately from the dissertation. In the United Kingdom, study programs of professional doctorates are frequently accredited by the relevant professional organizations (cf. Green and Powell 2005: 86ff.).

2.5.5 The Practice-Based Doctorate

The practice-based doctorate is a terminological specificity of the British university system as well, but it is also awarded in Australia. It denotes the award of doctoral degrees in Arts and in Design. While German universities, for example, award a doctoral degree in musicology or art history, the highest degree in the various fine arts as such (e.g. painting, sculpting, acting, singing, dancing) is called "*kuenstlerische Reife*" (which can be translated literally as "artistic maturity"). No doctoral degree is awarded in these fields.

The practice-based doctorate increased in importance with the integration of colleges of art into universities in the 1990s in the United Kingdom. The degree is awarded as a result of course work in the framework of which students are familiarised with theories and research methodologies and the presentation of a work of art or performance as a substitute for the dissertation. The presentation or performance is accompanied by a text in which the candidate explains how he or she has arrived at the result or product by applying research methods. This is regarded as generating new knowledge through practice. Successful candidates are also expected to demonstrate how their work of art is related to other works of art in the same field (theoretical, historical, critical, or visual context) and to evaluate possible effects. In the field of composition frequently not just one work is presented but a whole portfolio. In the oral examination, the work of art will be presented or performed and the candidate demonstrates on the basis of the accompanying text that she or he has sufficient knowledge and the appropriate skills to independently generate new knowledge.

The practice-based doctorate is contested in the United Kingdom because—compared to all other models of the doctorate—it shows the least proximity to the traditional notion of a dissertation. However, about half of all British universities offer such a doctorate (cf. Green and Powell 2005: 100ff.).

2.5.6 The "New Route" Doctorate

The model of the "new route PhD" (also called the integrated doctorate) was developed by ten British universities as a brand in 2001 with the purpose of attracting international students. In the meantime, it is offered by more than 30 British universities. The program basically consists of three (integrated) elements: a taught component in the area of research methods and subject specialisation, another taught component in the area of transferable skills and work on a dissertation (disciplinary or interdisciplinary). Admission can be granted right after having completed a Bachelor's degree. The taught components are frequently offered in the framework of related Master programs and accompany the whole 4 years envisaged for getting the degree. For the taught components 240 credit points are awarded. Requirements for the dissertation are similarly high as for the research doctorate.

However, in comparison to the research doctorate the taught elements are more important and also arranged in more detail with respect to the qualifications and competences to be acquired. Often there is also the possibility after having finished all the course work, to write a master thesis instead of a doctoral dissertation and finish with a master's degree.

In Germany, this model has become known as a "fast track PhD" and is offered in specific subjects at some universities. Although the Master's degree in Germany is required for admission into doctoral programs or acceptance as a doctoral candidate this model offers transition into the doctoral phase for particularly talented students immediately after earning their Bachelor's degree.

Basically the new route PhD, as well the fast track PhD, follow the American model of an integrated postgraduate education in which the master's level and the doctoral level are combined in terms of the course work to be done. However, the American model clearly separates the course work phase from the phase of writing a thesis, which follow each other in a sequence and are not integrated. This American two-phase approach results in high drop-out rates after having finished the course work or (compared to Europe) a rather long time working toward a degree (between 6 and 9 years). Despite the fact that a fast track to the doctoral degree is possible in exceptional cases in many European countries, the European University Association has recommended that the Master's degree be the rule for access into doctoral programs or the doctoral qualification phase.

2.5.7 Two Models of the Joint Doctorate

The model of the joint doctorate is characteristic for doctoral programs jointly offered by two or more universities which may be located in the same region, the same country or different countries. A study carried out by EUA (EUA 2005) about changes in doctoral education in Europe included a survey among member institutions. 18 % of responding universities confirmed that they offer joint doctorates. Leading countries in terms of the number of joint doctoral degree programs are Germany, Spain, France, Italy, the United Kingdom and the Netherlands.

In the EUA study (EUA 2005: 28ff.) the joint doctorate is characterised as follows:

- a joint curriculum for the taught components which has been developed in close cooperation among the participating institutions; the doctoral students take courses at several universities;
- an agreement signed by all participating institutions clarifying funding issues and other matters (e.g. mobility, quality assurance).

The certification of a joint doctorate is regulated in various ways: from the awarding of the degree from the university at which the candidate is enrolled, to a double degree on the basis of joint supervision (i.e. co-tutelle arrangements) and a joint degree.

Joint doctorates are predominantly awarded by universities (or more exactly by faculties and departments) cooperating in transnational networks. The advantages for doctoral students are that in most cases, phases of mobility are built into the program, and they often have more than one supervisor and additional access to further experts in their field who are members of the network. However, the actual practice differs from this ideal type. Joint doctorates have a higher degree of internationalisation and more opportunities for mobility, but they are often not based on a joint curriculum of the participating partner institutions.

A particular variant of the joint doctorate is the "European doctorate" which does not, however, yet exist in practice. The idea and an informal initiative came up at the beginning of the 1990s during a meeting of the Confederation of European Rectors' Conferences (an organization which has merged with the former CRE to become EUA). The "Doctor Europaeus", as the planned title was to be, has been contested until today, although there is a consensus about the promotion and improvement of European cooperation in doctoral education and the mobility of doctoral students (or candidates). Currently another initiative in this direction is being undertaken by the European Commission offering funding for joint doctoral programs emerging from partner universities of an Erasmus Mundus Program. The difficulty of putting the idea into practice is due to the fact that within Europe there is increasing competition for best talent among institutions and on a national level, a more competitive research policy and innovation strategy. Thus, the best talent is not easily "shared". Still, the discussion about the "Doctor Europaeus" has been revived in the context of the Lisbon Strategy to create a European Research and Innovation Area.

2.5.8 The Cooperative Doctorate

The cooperative doctorate is a model in which professors from universities and professors from (German) universities of applied sciences (the latter have no right to award doctoral degrees) jointly supervise a doctoral candidate who graduated from a university of applied sciences. Taught elements of such a degree are typically offered in the framework of a university graduate school or program while the research topic is often developed between the candidate and his or her professor from the university of applied sciences. The degree is awarded by the university. This model has emerged in the framework of attempts of research-oriented universities of applied sciences to acquire the right to award doctoral degrees, which so far has failed due to resistance coming from the universities and lack of political will.

2.5.9 The Industrial Doctorate

The industrial doctorate is mostly awarded in engineering fields and is a rather applied degree. Research work of the candidate is carried out, for example, in the R&D department of a company and is oriented towards the solution of a particular problem or issue. The research work is supervised by a senior engineer of the company while taught elements, theory and methodology are supervised by a university professor. Research topics frequently emerge from work in that company during an internship (see Borrel-Damian 2009).

As can be seen from this list there has been a considerable diversification in the types of doctoral degrees, some of which are clearly geared towards non-academic labor markets (e.g. the professional doctorate, the industry doctorate). However, only English-speaking countries, notably the United Kingdom, Australia and New Zealand have implemented a clear distinction (including terminological differentiation) between a research and a professional doctorate (see Neumann 2002).

At the same time, the differentiation of doctoral degrees has led to a shift in the phase in which decisions for an academic career are made, namely from the doctoral to the postdoctoral phase (see Fumasoli and Goastellec 2015). A 2010 survey of the academic profession involving eight European countries included an analysis of academic career paths (see Brechelmacher et al. 2015). The study identified the postdoc phase as a critical bottleneck. Not only has it become increasingly difficult to obtain employment as a postdoctoral researcher, but this phase has also become the most competitive while at the same time young researchers have to deal with unclear career paths and a high degree of job insecurity. In addition, perseverance and hard work usually do not automatically lead to a professorship. Many of the junior academics who were interviewed in the framework of the study claimed that getting a professorship was sheer good luck, serendipity or chance.

In some European countries, tenure track models have been introduced recently to provide clearer career progress for junior academics. But there are not enough of these positions and competition is fierce. Thus, many postdoctoral academics use this period to go abroad for some time in order to use a mobility experience as an added value to give them an edge in the ongoing competition. In addition, such a mobility phase helps to build up networks and accumulate social capital. Still, most young academics aim for a career in their home country and despite many positive experiences of a stay abroad, they encounter problems upon return. They have lost some of their local or national networks and their experience is not valued sufficiently. The analysis concludes that the postdoctoral phase is not only the most critical for an academic career, but it is also characterised by two bottlenecks, one at the beginning when trying to secure a postdoctoral position after completion of the doctorate and one at the end when trying to secure permanent or tenured employment.

However, the fact that the majority of doctoral degree holders enter an academic career, but only about one tenth of them eventually end up in a permanent professorial position makes the period between postdoc and professorship particularly interesting. It is a period often characterised by great uncertainty, frequently more than one fixed-term contract, possibly one or more job changes or a period of research abroad and last but not least a period in which many academics are starting a family. It is also a period about which there is not much research-based knowledge available.

Academic labor markets have been characterised by Musselin (2010) as being either external or internal. An internal academic labor market means that academics can progress upward within their higher education institution through evaluation and promotion, while an external academic labor market means a change of institution when the next step on the career ladder is being taken. Internal academic labor markets have been criticised as tending towards inbreeding, external academic labor markets have been criticised for leading to long periods of instability and job insecurity. In many European countries, the postdoc phase has been extended and it is during this phase that opportunities for a permanent career in academia are opening up. Those national higher education systems that have permanent teaching and/or research positions below the professorial level can provide more opportunities to stay in academia than those systems that offer only fixed-term contracts. Germany is a particularly problematic example in this respect as it offers basically no permanent contracts below the level of professorship and has also introduced time limits, i.e. young academic staff can be employed for up to 6 years before the doctorate and up to 6 years after the doctorate. Then it is either ‘up or out’ or short-term temporary contracts as researchers in externally funded projects.

2.6 The Extended Policy Field: Policy Questions and Data Needs

In recent years the need to reform doctoral education and training has been high on the policy agenda in many countries around the world as well as in a number of supra-national organizations. Increasingly the production of new knowledge, often a task and an aspiration of doctoral candidates, is no longer regarded as a purely academic affair but as a strategic resource in the emerging knowledge societies and economies. Thus doctoral education and training has become an object of institutional management, of national policy and of supra-national incentives, regulations and measures for better integration into existing knowledge and innovation systems. Furthermore, increasingly international competition for best talent can be observed.

At the same time public criticism of doctoral education and training has become more widespread: too long, too many dropouts, too specialised, questionable quality of supervision, lack of competences for non-academic labor markets. The answer to such criticism has been a shift away from the traditional continental European 'master-apprentice' model to a structuring of this qualification phase by framing it through doctoral programs, centres, schools or colleges and the addition of systematic curricular programs to offer theoretical, methodological and labor market related competences and skills. In fact, the reform of the European Bologna Process conceptualised innovative doctoral training as a third cycle of studies, following a Bachelor's degree (first cycle) and a Master's (second cycle) degree. The developments which have been described here currently have three observable consequences: First, the master-apprentice model is regarded as a phase-out model; second, the focus on a point in the framework of a rite of passage (i.e. defence and award of title) with an emphasis on the product "dissertation" is shifting to a focus on the process of doctoral education and training (its structures, content, quality); third, access to doctoral education and the process of getting a doctorate are increasingly embedded in a dense layer of regulations, criteria, defined rights and obligations, procedures of evaluation and controls of success—all in the name of improving quality, transparency and accountability. Doctoral degree holders are considered valuable contributors to innovation and knowledge transfer in knowledge economies and their numbers have become important elements of the key performance indicators of higher education institutions. Thus, their education and training can no longer be left to professors exclusively and we can observe an extended policy field for doctoral education reaching from institutional management, to national policies to supra-national reform agendas. Here a couple of examples how supra-national actors are trying to extend and influence the policy field.

The European Commission's 'Principles for Innovative Doctoral Training' (European Commission 2011) try to provide guidelines for national policy makers as well as institutional management on how to organise doctoral education. The paper is based on seven principles:

- Striving for research excellence.
- Offering an attractive institutional environment with proper career development opportunities.
- Embedding doctoral training into an interdisciplinary research environment.
- Exposing doctoral candidates to industry and other relevant employment sectors.
- Providing opportunities for international networking and mobility.

- Including transferable skills training into doctoral education and involving industry and businesses into the related curricular development.
- Providing transparent and accountable procedures for the life cycle of the doctoral phase from recruitment to graduation and career development by establishing a quality assurance system separate from the first and second cycle of studies.

In 2008, the European University Association (EUA) has established the EUA Council for Doctoral Education (EUA-CDE) in order to create "a strong voice for European universities on doctoral education both inside Europe and internationally..." (see EUA-CDE Website). Objectives of the work of the EUA-CDE are:

- To enhance the quality of doctoral education in European universities.
- To encourage and support the development of institutional policies and strategies.
- To improve the availability of data and information on doctoral education.
- To identify and monitor emerging trends in doctoral education.
- To act as a representative voice of European universities in the dialogue with other stakeholders.
- To contribute to strengthening the international dimension of doctoral programmes.
- To build and develop a strong link between education and research policies and strategies within Europe.
- To promote the doctorate and doctorate holders as careers upon which to build a knowledge-based society (http://www.eua.be/).

Contrasting the European Commission's Principles with EUA-CDE's objectives we can note that the European Commission's policy for doctoral education is more strongly geared towards non-academic labor markets than the objectives of the EUA-CDE. Apart from explicit references to non-academic labor markets and transferable skills training, the European Commission tends to use the concepts of 'research training' or 'doctoral education and training', thus emphasizing the training dimension envisaged for this phase of qualification while the EUA-CDE avoids the notion of 'training' but speaks of 'doctoral education'.

However, the EUA-CDE also notes that the first phase of reforming doctoral education in Europe by providing structure to the process of qualification and establishing management procedures has come to an end. As the new and upcoming challenges for doctoral education, it identifies demography, competitiveness and sustainability and announces a comprehensive policy paper for 2016 that is supposed "to set the tone for the next decade" (http://www.eua.be/).

With this we have some indications concerning future policy needs. From what has been discussed so far, it becomes clear that the decision to go for an academic career or opt for non-academic labor markets has shifted to the postdoc phase. This phase is currently characterised as a "bottleneck" (see Brechelmacher et al. 2015;

Fumasoli and Goastellec 2015) in which academic career aspirations are either becoming fulfilled or are broken leaving the young researchers concerned in increasingly precarious working conditions. Some European countries (e.g. Germany, France, Austria, Finland) have recognised the need to develop policies and career opportunities for postdoctoral researchers and shape this particular phase of qualification in a more targeted manner. Major policy questions are, for example, the status of postdocs, financial support of postdocs as well as the creation of working conditions which allow for the compatibility of work and family, the attractiveness of research careers as well as support for non-academic careers and improved opportunities for mobility between university and industry. Here are a few examples.

The German Federal Ministry for Education and Research is supporting a major national report analysing the situation of postdocs (status, funding, career opportunities, potential of tenure track models) and developing appropriate policies for a better compatibility of working and family life (http://www.buwin.de/buwin/2013/).

The French Ministry of Higher Education and Research has developed the CIFRE Program (Industrial Agreement of Training through Research) which offers 1300 three-year fellowships each year for PhD students who sign a full-time work contract with a French company while being enrolled in a doctoral course at a university at the same time. In this program the research work is carried out inside the company while the university provides course program and a supervisor (http://www.phdinfrance.net/txt/cifre.pdf).

A recent study with interviews being carried out in Austria and Finland (see Brechelmacher et al. 2015; Campbell and Carayannis 2012) looked at the phenomenon of cross-employment, which seems to have increased in both countries. Cross-employment denotes parallel employment inside and outside academia at the same time. It is a form of employment for at least three groups of postdocs:

- The first group consists of young academics with precarious (i.e. fixed-term and part-time) contracts within academia who need to complement their meagre salaries by getting a second job outside academia.
- The second group consists of younger as well as more senior academics who hold positions within academia but have a professional practice (e.g. a law practice, a clinical job or an architecture office) at the same time.
- The third group consists of academics who explicitly do not wish to work fully and only in one institution.

People in cross-employment situations stated a number of advantages and disadvantages. Advantages were in particular, broader perspectives, advancement of competences, well-developed networks and the development of transfer skills. Disadvantages were seen in work and time pressure, tensions between the different work cultures and the perpetuation of short-term contracts. However, the exploratory study needs to be complemented by a fuller and broader analysis of the phenomenon of cross-employment and its positive and negative sides.

Concerning the data needs these will be explored in more detail in another section of this book (see Part II in this book; also see Auriol et al. 2013), however, it becomes clear from what has been discussed so far that there is an urgent need to find out more about the first and possibly further destinations of doctoral degree holders and analyse their transition into stable employment. Of particular policy interest will be the proportion of doctoral degree holders finding employment outside academia as this is a key indicator for the extent to which a knowledge-based society and economy has been achieved.

2.7 Conclusions

Certainly, national as well as disciplinary cultures continue to influence doctoral education and training and show more differences than similarities. However, Fumasoli and Goastellec (2015) have pointed out that recruitment patterns and career progress in academic markets gradually have been standardised and formalised across Europe. This is more pronounced at the level of senior positions as professors still play an important role when it comes to recruiting early career researchers. This is complemented by a trend (e.g. through tenure track models and state regulations pertaining to career progress) towards increasingly internal academic labor markets (see Musselin 2010) in those countries, which traditionally were relying on external academic labor markets. And to make the picture even more complex we also can observe the emergence of increasingly international external academic labor markets in so far as mobility at the postdoc level has become more common and is often shaped by a year or two of working at a university or research centre abroad.

Concerning general trends for doctoral degree holders with regard to their transition into employment, we can note that (a) non-academic labor markets are increasingly more open to recruiting doctoral degree holders; (b) doctoral degree holders have a clearly lower rate of unemployment than persons with a higher education degree but no doctorate; (c) a doctoral degree is a prerequisite, i.e. a necessary but not sufficient condition, to enter academia. Instead, it tends to be the postdoctoral phase now in which decisions have to be made either to stay in academia or move into professional jobs outside academia.

References

Auriol L, Misu M, Freeman R (2013) Careers of doctorate holders: analysis of labour market and mobility indicators. OECD Science, Technology and Industry working papers 2013/04. OECD, Paris

Blume S, Amsterdamska O (1987) Post-graduate education in the 1980s. OECD, Paris

Borrel-Damian L (2009) Collaborative doctoral education: university-industry partnerships for enhancing knowledge exchange. European University Association, Brussels

Bourner T, Bowden R, Laing S (2000) Professional doctorates: the development of researching professionals. In: Bourner T, Katz T, Watson D (eds) New directions in professional higher education. SRHE and Open University Press, Buckingham, pp 214–225

Brechelmacher A, Park E, Ates G, Campbell D (2015) The rocky road to tenure. Career paths in academia. In: Fumasoli T, Goastellec G, Kehm BM (eds) Academic work and careers in Europe. Trends, challenges, perspectives. Springer, Dordrecht, pp 13–40

BuWiN Website: http://www.bmbf.de/de/24781.php. Accessed on 6 Feb 2015

Campbell DFJ, Carayannis EG (2012) Lineare und nicht-lineare Knowledge Production: innovative Herausforderungen für das Hochschulsystem. Zeitschrift für Hochschulentwicklung 7 (2):64–72

CIFRE Website: http://www.phdinfrance.net/affpage.php?name=cifre. Accessed on 5 Feb 2015

Clark BR (ed) (1993) The research foundations of graduate education: Germany, Britain, France, United States, Japan. University of California Press, Berkeley

Clark BR (1994) Places of inquiry: research and advanced education in modern universities. University of California Press, Berkeley

Clark BR, Neave GR (eds) (1992) The encyclopaedia of higher education (4 volumes). Pergamon, Oxford

EUA (2005) Doctoral programmes for the European Knowledge Society. Brussels. URL: http://www.eua.be/index.php?id=48&no_cache=1&tx_ttnews%5Btt_news%5D=335&tx_ttnews%5BbackPid%5D=1

EUA-CDE Website: http://www.eua.be/cde/about-euacde.aspx. Accessed 6 Feb 2015

European Commission (2011) Principles for innovative doctoral training. URL: http://ec.europa.eu/euraxess/pdf/research_policies/Principles_for_Innovative_Doctoral_Training.pdf. Accessed 6 Feb 2015

Fumasoli T, Goastellec G (2015) Global models, disciplinary and local patterns in academic recruitment processes. In: Fumasoli T, Goastellec G, Kehm BM (eds) Academic work and careers in Europe. Trends, challenges, perspectives. Springer, Dordrecht, pp 69–93

Golde CM, Walker GE (eds) (2006) Envisioning the future of doctoral education. Preparing stewards of the discipline. Carnegie essays on the doctorate. Jossey-Bass, San Francisco

Green H, Powell S (2005) Doctoral education in contemporary higher education. SRHE and Open University Press, Maidenhead, New York

Gumport PG (1992) Graduate education: comparative perspectives. In: Clark BR, Neave GR (eds) The encyclopaedia of higher education. Pergamon, Oxford, pp 1117–1127

Huisman J, Meek VL, Wood FQ (2007) Institutional diversity in higher education: a cross-national and longitudinal analysis. High Educ Q 61(4):563–577

Kehm BM (2004) Developing doctoral degrees and qualifications in Europe: good practice and issues of concern. A comparative analysis. In: Sadlak J (ed) Doctoral studies and qualifications in Europe and the united states: status and prospects. UNESCO-CEPES, Bucharest, pp 279–298

Kehm BM (2009) New forms of doctoral education and training in the European higher education area. In: Kehm BM, Huisman J, Stensaker B (eds) The European higher education area. Perspectives on a moving target. Sense, Rotterdam, pp 223–241

Kehm BM (2012) Die deutsche Doktorandenausbildung aus europäischer Perspektive. In: Kehm BM, Schomburg H, Teichler U (eds) Funktionswandel der Universitäten. Campus, Frankfurt am Main, pp 340–355

Musselin C (2010) The market for academics. Routledge, London

Nerad M (2004) The PhD in the US: criticisms, facts and remedies. High Educ Policy 17 (2):183–199

Nerad M, Heggelund M (eds) (2008) Toward a global Ph.D.? Forces and forms of doctoral education worldwide. University of Washington Press, Seattle, WA

Neumann R (2002) Diversity, doctoral education and policy. High Educ Res Dev 21(2):167–178

OECD (2012) Education at a glance 2012: OECD indicators. OECD Publishing, Paris

Park C (2005) New variant PhD: the changing nature of the doctorate in the UK. J High Educ Policy Manag 27(2):189–207

Rhoades G (1991) Graduate education. In: Altbach PG (ed) International higher education: an encyclopaedia. Garland, New York, pp 127–146

Sadlak J (ed) (2004) Doctoral studies and qualifications in Europe and the United States: status and prospects. UNESCO-CEPES, Bucharest

Slaughter SA, Leslie LL (2000) Academic capitalism: politics, policies and the entrepreneurial university. Johns Hopkins University Press, Baltimore

Teichler U (ed) (2006) The formative years of scholars. Portland, London

Teichler U (2008) Diversification? Trends and explanations of the shape and size of higher education. High Educ 56(3):349–379

Teichler U (2014) Doctoral education and training: a view across countries and disciplines. In: de Ibarrola M, Anderson LW (eds) The nurturing of new educational researchers. Dialogues and debates. Sense, Rotterdam, pp 1–25

UNESCO Forum on Higher Education, Research and Knowledge (2008) Trends and issues in postgraduate education: challenges for research. International experts' workshop: final report. UNESCO, Paris

The Careers of Doctorate Holders (CDH): Principles for Broad International Surveys—The CDH Example

3

Laudeline Auriol

3.1 Introduction

Highly educated and skilled people are central to the creation, commercialisation and diffusion of knowledge. Among them, doctorate holders are both the most qualified in terms of educational attainment and those who have been trained to conduct research. Their contribution to the advancement of knowledge is therefore of particular interest to practitioners in charge of steering research and innovation systems. While regarded as essential in a knowledge-based and complex economy, the training of doctoral graduates and researchers is also a long and costly effort. Since 2000, doctoral awards have increased at the same pace as, or even slightly more rapidly than other degree awards. Measuring the return on investment of such long education and training has drawn policy attention. Generic statistical sources on human resources, such as censuses and labor force surveys, are however not fit to provide a full picture of the employment patterns and the contribution of doctorate holders. It is with this in mind that the OECD launched a collaborative project with the UNESCO Institute for Statistics and Eurostat in 2004 that aims to address the evidence gaps about this population group and develop internationally comparable indicators on the labor market, career path and mobility of doctorate holders.[1]

After a thorough review of user needs in terms of indicators, a network of experts (comprising official statisticians) worked to identify the various data sources that could be utilized at national level to build registers of doctoral graduates or produce

The opinions expressed in this paper are the sole responsibility of the author and do not necessarily reflect those of the OECD nor those of its member countries' governments.

[1] All information on the CDH project can be found at: www.oecd.org/sti/cdh

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statistical data. The expert group also collaborated with the three intergovernmental organizations to develop technical guidelines that comprise three components: a model survey questionnaire, methodological guidelines and a set of output tables for collecting data at the international level.

After a pilot in 2005, two large scale data collections were conducted in 2007 and 2010. 25 countries participated in each round and a rich set of data was made available and analysed (Auriol 2010; Auriol et al. 2013). In the context of the 2010 CDH data collection cycle, the OECD also attempted to encourage the use of microdata for purposes other than benchmark-type indicator construction and reporting, although participation in this strand of work was constrained to a limited number of countries.

In the remainder of this chapter, are described in more detail the underlying concepts and methodology of the CDH project (i.e. the technical guidelines) and the way they are implemented at national level.

3.2 Underlying Concepts and Methodology

The underlying concepts and methodology of the CDH project are described in the technical guidelines developed by the above mentioned network of experts (Auriol et al. 2012).[2] The technical guidelines are composed of: (i) the methodological guidelines; (ii) a core model questionnaire and instruction manual; and (iii) the output tables used for reporting data at the international level and related definitions. The technical guidelines are currently in their third edition. The latest edition builds on the the two initial large scale data collections, which were based on the previous editions of the technical guidelines released in 2007 and 2010.

3.2.1 The Methodological Guidelines

The methodological guidelines constitute the basic document which defines the target population and gives the instructions for the survey methodology, data collection, estimation and processing.

The target population consists of individuals who at the reference date fulfill the following criteria:

- have an education at ISCED 1997 level 6 (doctorate) obtained anywhere in the world, and
- are resident (permanent or non-permanent) within the national borders of the surveying country.[3]

[2] The detailed CDH guidelines are available here: http://dx.doi.org/10.1787/5k4dnq2h4n5c-en

[3] ISCED (the International Standard Classification on Education) was revised in 2011 and its implementation is expected to start in 2014. The equivalent of ISCED 1997 level 6 will be ISCED 2011 level 8.

The choice of this definition stems from the following needs: (1) to know the total number of doctorate holders at the national level, which in some countries could not be derived from the existing data sources or surveys; (2) to have an overview of the career of doctorate holders at different stages of their career and at varying ages; (3) to cover, in the surveying country, doctorate holders of foreign origin with a view to understand international mobility flows.

The implication of this choice is that the survey to be carried out is of a cross-sectional retrospective nature i.e. it covers the whole population at a certain point of time (which is the agreed reference date in the methodological guidelines) and it includes retrospective questions. This approach is very similar to that of the Survey of Doctorate Recipients (SDR) conducted every other year by the National Science Foundation (NSF) in the United States, and which has greatly inspired the CDH survey. However, it differs from approaches in other countries, such as France or the United Kingdom, which are based on graduate and/or cohort surveys and essentially focused on early career stages, while including in some cases a longitudinal element. The CDH survey nevertheless contains questions about the early career period and also specifically targets recent doctorate holders, defined as those who received their doctoral degrees in the last 2 years.

One of the characteristics of the CDH project is to accommodate the provision of data from different statistical sources (e.g. censuses, labor force surveys, national registers) while proposing a specific survey instrument. The methodological guidelines describe in some length the different data sources that can be used either for building a national register of doctorate holders that will serve as a sampling frame for a dedicated CDH survey or for producing the CDH data as requested in the output tables. Building and maintaining a national register of doctorate holders at national level proved to be particularly challenging. Table 3.3 in the annex gives examples on how several countries that have conducted CDH dedicated surveys approached this task.

Recommendations are also given in the methodological guidelines on data collection methods, sampling, the treatment of unit non-response and non-response surveys, imputation, weighting and calibration.

3.2.2 The CDH Model Questionnaire

Only a CDH dedicated survey based on the CDH model questionnaire has the potential to provide a comprehensive picture of the employment and mobility patterns of doctorate holders. The model questionnaire developed in the framework of the CDH project addresses the following aspects through six different modules: characteristics of doctoral education, early career research positions, employment situation, international mobility, research career related experience and personal characteristics. Questions on earnings as well as on perception and satisfaction at work are included among these and the latest edition added new questions on competencies.

With few exceptions, all questions included are drawn from already existing surveys or rely on existing experience and have been extensively discussed among the members of the CDH network of experts. They are also reviewed and adjusted after each data collection round. All variables and breakdowns to be collected are defined on the basis of internationally agreed definitions and classifications.

During the implementation of the CDH project, a number of policy and analytical needs appeared that the CDH expert group sought to address through the inclusion of new modules/questions. A couple of these are worth mentioning here.

With a view to know more about the ‘postdoc’ phenomenon, it was decided to include a separate module on ‘early career’ in the second edition of the model questionnaire. Preliminary work had sought to develop an international definition of a ‘post-doctorate’, but this proved to be impossible due to the heterogeneity of existing post-doctorate status and positions both across institutions in one country and across countries. Instead, the CDH expert group preferred to develop an approach that would seek to qualify common characteristics of early careers of doctorate holders, some of which could be assimilated to post-doctorates. This approach was based on a similar and parallel effort under way in the United States.

The question of skills and competencies of doctorate holders and researchers has also become prominent in the policy debate and some countries had already sought to measure competencies in their national surveys before it was decided to develop a common set of questions for the CDH model questionnaire. The latest edition of the model questionnaire therefore includes new questions on competencies that rely on existing experiences in Belgium, the Russian Federation and the United Kingdom.

Only those questions that are necessary for international reporting are mandatory in the CDH model questionnaire, with the remaining questions optional (e.g. the new questions on early career or competencies). Adding questions for national purposes is possible. Flexibility about the way to organise the sequence of questionnaire modules is also given.

Finally, the model questionnaire includes a manual with detailed instructions on how to complete it.

3.2.3 The Output Tables

The output tables are used for reporting the data at the international level. They consist of 33 mandatory tables and 7 optional tables covering the following areas: personal characteristics, education characteristics, employment situation and perception, international mobility (inward and outward) and scientific output.

Detailed metadata are collected together with the statistical data in order to assess data coverage and consistency with the proposed definitions and methodology as well as the comparability of the data with that of the other countries.

The data are processed by the OECD in an internal database, which is subsequently used to produce a set of indicators made available online and for further analyses.

3.2.4 The Microdata Work

To address a number of policy and analytical questions, microdata derived from the 2010 data collection were also used for more in-depth investigation. Four key areas of work were identified: (1) early careers of doctorate holders; (2) job-to-job mobility; (3) international mobility and (4) competences and skills of doctorate holders. Using a data coding guide provided by the OECD, ten volunteer countries harmonised their microdata sets to implement tabulations and econometric analyses using a common programming code developed by two national participant institutes: CSIC (Spain) and NISTEP (Japan). Each topic was led by a national participant organization: NISTEP (Japan) for early careers, DGEEC (Portugal) for job-to-job mobility, CSIC (Spain) for international mobility and ECOOM (University of Ghent, Belgium) for competences and skills.

In addition, and with a view to extend the number of countries for which comparisons could be carried out, a special effort was made to define common populations of doctorate holders among surveys of university graduates available for France, Japan and the United Kingdom, and sub-samples within CDH surveys carried out in other countries. These comparisons were carried out under the 'early career module' of the project.

Access to and use of microdata has been instrumental in conducting comparative analyses that go beyond traditional benchmark indicators and facilitate comparisons with data from early destination surveys.

3.3 Survey Implementation: National Practices

The second large scale data collection conducted in 2010–2011 benefitted from the participation of 25 countries.[4] The data to be reported by the participating countries were on the situation of doctorate holders as of 1 December 2009. In this section, we explain how the above described methodology has been implemented by the reporting countries and how some differences in the data sources and coverage of the target population may affect the comparability of the data.

3.3.1 Main Data Sources Used to Report CDH Data

One of the most difficult challenges in the CDH exercise is for each country to find the best way to build a directory of its doctoral graduate population. This is paramount in particular to the conduct of a survey using the CDH dedicated questionnaire instrument. Recommendations in the methodological guidelines

[4] Belgium, Bulgaria, Croatia, Denmark, Finland, Germany, Hungary, Iceland, Israel, Latvia, Lithuania, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovenia, Spain, Sweden, Switzerland, Chinese Taipei, Turkey, United States.

detail how to approach such a challenge and Table 3.3 in the annex shows several examples on how some countries have done it.

In the end, we distinguish two different groups of countries that use two diverse approaches for producing CDH data:

1. Countries that use the CDH model survey questionnaire and hence have built a specific register of doctorate holders;
2. Countries that employ already existing surveys and/or registers (or administrative data).

In addition, a number of countries conduct graduate surveys that do not cover the full CDH target population and are not harmonised at the international level but can be used for making comparisons with CDH results about early career stages, using microdata on comparable (sub)-populations.

Table 3.1 below proposes a typology of these data sources showing a few examples that are commonly used.

Among the countries that participated in the latest data collection, we find two economies which used their labor force survey to report CDH data (Germany and Switzerland), four relying on their population registers (Denmark, Finland, Norway and Sweden) and one using an already existing database (i.e. Chinese Taipei).[5] All the other countries conducted a CDH dedicated survey as recommended in the methodological guidelines.

The United States, however, represent a case in point. It uses data derived from long and well established surveys, which to a great extent inspired the CDH survey.

As we explain below, the use of these different data sources has an impact on both the coverage of the target population and the coverage of the reported variables.

3.3.2 Differences in Coverage

The target population as defined in the CDH methodological guidelines is: 'all individuals who have an education at ISCED 6 level (doctorates) obtained anywhere in the world and who are resident (permanent or non-permanent) within the national borders of the surveying countries'. The main challenge in operationalising this definition concerns the coverage of foreign citizens and those who obtained their doctoral degree abroad.

This challenge is less problematic in countries which rely on labor force surveys (or censuses) and register data (although some of the foreign doctoral graduates may not be fully registered in the latter administrative sources). For countries which

[5] Germany however has since decided to move to a dedicated survey that was conducted for the first time in 2012. This survey not only covers doctorate holders, but also other higher education graduates.

Table 3.1 Typology of international data sources used for reporting CDH-type data

	Coverage of doctoral population	Size of doctoral population	Type of relevant information	Other remarks
Careers of doctorate holders surveys	Good	Good	Good	
Mainstream household and population surveys				
Censuses	Full	Good	Limited	Infrequent; doctorate not always identified
Labour force surveys	Full	Limited	Limited	Doctorate not always separately identified
Administrative sources				
Nordic type population registers	Good	Good	Limited	
Social security registers	Good	Good	Limited	Doctorate not always separately identified
Migrant information	Good	Good	Limited	Doctorate not always separately identified
Graduate surveys				
United States (National Science Foundation)				
Survey of Doctorate Recipients	Good	Good	Good	Similar to CDH survey
Survey of Earned Doctorates	Early career	Good	Good	
Japan				
Survey of Recent Doctoral Graduates	Early career	Good	Good	Limited international comparability
United Kingdom				
Destinations of Leavers from Higher Education (DLHE)	Early career	Good	Good	Limited international comparability
Longitudinal DLHE (L DLHE)	Early career	Good	Good	Limited international comparability
France				
'Géneration' surveys	Early career	Good	Good	Limited international comparability

Source: OECD Secretariat

have dedicated CDH surveys, foreign citizens or graduates who obtained their doctorate abroad are in most cases under-represented.

In the case of the United States, the sample of doctorate holders has been updated with foreign citizens and those with non-US doctoral degrees at the time of the decennial censuses until the latest 2000 decennial census round. After 2000, the target population only covers those graduates (including foreign citizens) with doctoral degrees obtained in the United States.

It may also be challenging to achieve full coverage of other segments of the target population, e.g. those who received their doctoral degrees in earlier years, those who are inactive or unemployed. Furthermore, once constructed, keeping a register of doctorate holders updated with the new graduates is difficult in certain countries.[6] In such cases, there are a few other limitations regarding the coverage of the target population in some countries:

- For Belgium, Germany, the Netherlands and Spain, data refer only to graduation years from 1990 and onwards.
- For Romania, unemployed and inactive doctorate holders are underestimated.
- For the Russian Federation, data relate only to those doctoral graduates employed as researchers and teachers.
- For Spain, there is limited coverage of doctorate holders for the years 2007–2009.
- For the United States, data exclude doctorate holders in the humanities.

It is also worth mentioning that while countries that use labor force surveys and register data achieve a better coverage of the target population, they can only report a limited number of variables concerning the main population, labor force and employment characteristics of doctorate holders. They do not include specific CDH variables such as perception of employment situation or international mobility.

Countries using labor force surveys are also limited by the sample size of the doctorate holder population for reporting on certain variables.

Additional country details are found in Table 3.2 below.

[6] This may be due to several reasons: lack of resources and/or difficulties to access the related information (e.g. Spain); or difficulties in locating some of the recent doctoral graduates who may be inactive, unemployed or abroad (e.g. for a post-doc).

Table 3.2 Main characteristics of the national CDH primary data sources and surveys—2010 data collection

Country	Primary data source	Reference year(s)	Web based survey	Sample or census size (value) and/or sample rate (%)	Sampling method	Response rate
Belgium	CDH dedicated sample survey	2009	Yes	–	Stratified sampling	28 %
Bulgaria	CDH dedicated sample survey	2009	No	2,000/13 %	Stratified sampling by region	55 %
Croatia	CDH dedicated sample survey	2009	On-line questionnaire available on the website of CBS Croatia and paper questionnaire	2,502/28 %	Stratified sampling by age, sex and fields of science	43 %
Denmark	Register data	2008/2009	–	–	–	–
Finland	Register data	2008	–	–	–	–
Germany	Labour force survey	2009	–	–	–	–
Hungary	CDH dedicated census	2009	Electronic and paper questionnaires	–	–	23 %
Iceland	CDH dedicated census	2009	Internet survey. The respondents were sent a username and password with a paper letter	600/30 %	Random sampling	61 %
Israel	CDH dedicated sample survey	2009	Paper questionnaire sent by mail, internet questionnaire and CATI (Computer-Assisted Telephone Interviewing)	7 %	Stratified sampling by sex, age and economic branch/occupation	82 %
Latvia	CDH dedicated sample survey	2009	Computer assisted face-to-face or telephone interviews and by e-mail	43 %	–	65 %
Lithuania	CDH dedicated sample survey	2009	Paper questionnaire only	1,408/25.7 %	Stratified sampling by age and fields of science	57 %

(continued)

Table 3.2 (continued)

Country	Primary data source	Reference year(s)	Web based survey	Sample or census size (value) and/or sample rate (%)	Sampling method	Response rate
Malta	CDH dedicated census	2009	Paper postal survey	556	–	75 %
Netherlands	CDH dedicated sample survey	2009	Internet survey (CAWI)	43 %	–	54 %
Norway	Register data				–	
Poland	CDH dedicated sample survey	2008	CDH e-questionnaire	40 %	–	7 %
Portugal	CDH dedicated sample survey	2009	Web and paper questionnaires	30 %	Stratified sampling by sex, age class, field of science and year of doctorate awarded	71 %
Romania	CDH dedicated sample survey	2008	–	15,215	–	49 %
Russian Federation	CDH dedicated sample survey	2009	–	3,450/1 %	Stratified sampling by region, age and fields of science	–
Slovenia	CDH dedicated sample survey	2009	Postal and telephone questionnaire	2,114/28.5 %	Stratified sampling by sex, age groups, doctorate holders and main fields of science	66 %
Spain	CDH dedicated sample survey	2009	Yes + paper + interviews	6,000	Stratified sampling by region and age	69 %
Sweden	Register data	2009				
Switzerland	Labour force survey	2009	–	–	–	–
Chinese Taipei	Administrative sources	2009				

Turkey	CDH dedicated sample survey	2009	Combination of face-to-face, web-based and postal survey	10,433/10 %	Stratified sampling by sex and age group	78 %
United States	CDH dedicated sample survey	2003/2008	Paper questionnaire, online questionnaire, computer assisted telephone interview	40,000/6 %	Stratified sampling by citizenship, race/ethnicity, disability status, gender, degree field	81 %

Source: OECD, OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Annex

Table 3.3 Description of data sources used in selected countries to build the CDH survey frame

Name of national data source used to build the survey frame	Data source type	Date(s) of creation and major changes	Limits of legal right of access to information within the data source	Information available in data source	Groups of units covered in the data source
Belgium					
CREF data base (Walloon universities)	National universities	1990	The National Privacy Commission determines the legal right of access	National register ID	None
ECOOM data base (Flemish universities)	National universities	1990	The National Privacy Commission determines the legal right of access	National register ID	None
Bulgaria					
Supreme Attestation Commission	Administrative	Updated annually		Name, date of birth, address, date of award of the degree	Individual information
Croatia					
Census of population and housing 2001	Population and housing census	2001, no major changes	CBS is authorized to use contact details of individuals	County, city/town/municipality of residence, address, year of birth, gender	7,443 doctors of science
Database of doctors of science who obtained their doctoral degree from 2001 to 2009	Survey on doctorate recipients conducted annually in CBS	2009, no major changes	CBS is authorized to use contact details of individuals	Personal information, former education, field of science and field of education of thesis, employer	3,540 doctors of science
Database of scientists in Croatia by Institute Ruđer Bošković	Research institute which keeps a public database of scientists	2009, no major changes	Public information, available on Internet	Home addresses, contact details, field of science, employers	4,094 doctors of science

Register of researchers by Ministry of Science, Education and Sports	Persons performing scientific activity pursuant to the Scientific Research and Higher Education Act are entered in the Register	2009, no major changes	CBS is authorized to use contact details of individuals	Personal information, field of science and employer	9451 doctors of science
Iceland					
All Icelandic universities	Employee list of all doctorate holders	2000 and ongoing. Updated in 2007	No particular limits of access	Name, gender, age, name of diss., field of study, year of graduation	Males, females, other nationalities, all ages, all fields of study
Women's History Museum	Register of Icelandic women who hold a PhD degree	2000 and ongoing. Updated in 2007 and 2009	No particular limits of access	Name, age, name of diss., field of study, year of graduation, marital status, sometimes personal CV	Females, all ages, all fields of study
Previously conducted surveys on doctorate holders	CDH survey 2006 along with an informal survey in 2005	2005 and 2006. Updated in 2007 and 2008/2009			Males, females, other nationalities, all ages, all fields of study
National libraries/ University libraries	A list of PhD dissertations at the National and University Library of Iceland	List was created in 2002 and updated in 2007 and 2009 (early year)	No particular limits of access	Name, gender, age, name of diss., field of study, year of graduation	Males, females, other nationalities, all ages, all fields of study
Morgunblaðið newspaper	Announcements of completed doctoral degrees	Updated every year since 2000	No particular limits of access	Name, gender, age, name of diss., field of study, year of graduation, marital status, sometimes personal CV	Selected information

(continued)

Table 3.3 (continued)

Name of national data source used to build the survey frame	Data source type	Date(s) of creation and major changes	Limits of legal right of access to information within the data source	Information available in data source	Groups of units covered in the data source
Homepages of all major research organizations	Homepages were scanned for information on employee education	List compiled in 2000 and updated 2006, 2008 and early year 2009	No limit of access	Name, gender, education level, type of position	Employed doctorate holders
Iceland's ten largest private companies in R&D	A list of PhD holders working for these companies	Updated every year	N/A (people chose to respond to our emails or not)	Name, gender, education level, type of position	Employed doctorate holders
An ad on Rannis' homepage	PhD holders were encouraged to contact Rannis through an ad on its homepage	2006 and 2008	N/A (people chose to respond to our ad or not)		Mostly information on R&D funding applicants
Rannis's email list of PhD holders	Rannis keeps a list of all those that have contacted Rannis about funding opportunities	Updated about 2–4 times a year	No limit if the information is only used internally (not given to outside agents)	Name, gender, education level, type of position, professional CV	Mostly information on R&D funding applicants
Lithuania					
The Register of Careers of Doctorate Holders from the Ministry of Education and Science	National register of education	Updated in November 2009	The right only for preparation survey frame and for formation output tables	The main data source for identification of doctorate holders	Doctorate holders, age below 70
Netherlands					

Starting the CDH survey, there was no usable survey frame of PhD holders at hand. The survey frame was based on the university PhD records	Dutch universities. Except Tilburg University and University of Amsterdam. The information from the universities refers to the academic year and not to the calendar year. That is why the 2009 number of PhDs is low	May 2010	Due to the Dutch law on statistics StatNeth has disposition of the national universities data sources	This information is quite varied between universities. Similar on each individual doctorate holders are Given name(s) Last name First name Date of birth Sex Certification day	PhD holders who are residents of the Netherlands, and who obtained their doctorate degree from Dutch universities
Poland					
Registry of Polish Science Database 'Polish Science'	National Register of Education	1990—creation of the Registry ('Polish Science' database)	Date of birth, address, citizenship are confidential	The Polish Science database contains information on approximately 120,000 persons holding at least a PhD degree, including about 98,000 persons of up to 70 years of age	
Portugal					
CDH06	Previously conducted survey of doctorate holders	2007	Not applicable	All CDH data	Doctorates
R&D Survey 2008	R&D statistics	2009	Not applicable	Biographic, academic, professional and R&D data	Researchers
National Register of Academic Staff 2009	Higher Education Survey	2010	Not applicable	Biographic, academic and professional data	Academic staff

(continued)

Table 3.3 (continued)

Name of national data source used to build the survey frame	Data source type	Date(s) of creation and major changes	Limits of legal right of access to information within the data source	Information available in data source	Groups of units covered in the data source
Doctoral degrees concluded in/or recognized by Portuguese universities 1970–2009	National universities	2010	Not applicable	Biographic and academic data	Doctoral degrees
Slovenia					
Joint file of doctorate holders on the basis of annual statistical surveys on graduates for the 1989–2009 periods	Statistical surveys	From 1989 to 2009	Internal source within SORS—standard rules/procedures for dealing with individual data within SORS were respected	Country of completion of advanced research qualification, field of science of advanced research qualification, date of start and grant of advanced research qualification, country of previous university degree	From this survey we have obtained all doctorate holders who have had doctorates in Slovenia from 1989 to 2009. We obtained with this source 64 % of the total doctorate holders
Statistical Register of Employment	Statistical register	Reference date: 31. 12. 2009	Internal source within SORS—standard rules/procedures for dealing with individual data within SORS were respected	Year of employment, location of employment, sector of employment, occupation, employment status, type of position, number of hours per week, advance research qualification	We obtained with this source 12 % of the total doctorate holders and for 89 % of doctorate holders, data on employment

Register of Unemployed Persons	Administrative register	Reference date: 31. 12. 2009	Administrative register managed by the Employment Office of Slovenia—data from the register are delivered to SORS (on the basis of Statistical Law and Program (5-year, annual) of official statistics	Unemployed persons with advance research qualifications	We obtained with this source data 0.19 % of the total doctorate holders
2002 Population Census	Population census	Reference date: 31. 3. 2002	Internal source within SORS—standard rules/procedures for dealing with individual data within SORS were respected	Advance research qualification	We obtained with this source data 24 % of the total doctorate holders
Central Population Register	Administrative register	Reference date: 31. 12. 2009	Administrative register managed by the Ministry of Interior of Slovenia—data from the register are delivered to SORS (on the basis of Statistical Law and Program (5-year, annual) of official statistics	Sex, year of birth, citizenship/resident status, place of birth, country of citizenship	We have acquired from CPR available information for all doctorate holders
Turkey					

(continued)

Table 3.3 (continued)

Name of national data source used to build the survey frame	Data source type	Date(s) of creation and major changes	Limits of legal right of access to information within the data source	Information available in data source	Groups of units covered in the data source
Turkish Education Database	National register of education and population and housing census	2007	**	Gender, date of birth, address, education level, national ID	
National Register of Active Academic Staff	Other	2009	**	Gender, national ID, academic title, name of employer (university, department, faculty)	
National thesis database	Other	2009	**	National ID, name, surname, title of thesis, graduated university, faculty)	
Researcher database	Other	2010	**	Gender, national ID, academic title, name of employer (university, department, faculty)	
United States					
Survey of Earned Doctorates	Previously conducted survey of doctorate recipients	Annual since 1958	Individual records (without personal identifiers) only available through licensing agreements to US educational or non-profit organizations	Demographic information; education history; financial support; time to degree; post-graduation plans	Individual doctorate recipients

Source: OECD, OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

**In censuses and surveys that are related to the working areas of the Institute, the TurkStat Presidency is authorized to request directly the data and information which are deemed necessary for the production of official statistics, in all mediums and from all statistical units, in the form, period and standards specified by the Presidency. The Presidency is also authorized to investigate and control the accuracy of information or data, request additional information, and depending upon the results, to determine the genuine information and data

References

Auriol L (2010) Careers of doctorate holders: employment and mobility patterns. OECD Science, Technology and Industry working papers, 2010/04. OECD Publishing. doi: 10.1787/5kmh8phxvvf5-en

Auriol L, Schaaper M, Felix B (2012) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators—Third edition, OECD Science, Technology and Industry working paper 2012/7. OECD Publishing, Paris. doi: 10.1787/5k4dnq2h4n5c-en

Auriol L, Misu M, Freeman R (2013) Careers of doctorate holders: analysis of labour market and mobility indicators. OECD Science, Technology and Industry Indicators working papers 2013/04. OECD Publishing. doi: 10.1787/5k43nxgs289w-en

Doctorate Holders' Labor Market and Mobility: The Academic Career as the First Choice

4

Laudeline Auriol, Toshiyuki 'Max' Misu, and Fernando Galindo-Rueda

4.1 Introduction

Doctoral graduates account for a relatively small proportion of the overall population but their importance is widely recognised (OECD 2010). Having benefitted from highly specialised research training and produced an original contribution to science, doctorate holders are expected to play a key role in the knowledge economy as they stand in a position to drive forward advances in science, technology and knowledge about society. Evidence on the careers of doctorate holders (CDH) and their contribution to science, innovation and the economy is of high relevance not only to policy decision makers and governments who finance the training of this group of individuals and support their integration in the innovation system; but also to prospective employers in search of specific skills for their workforce; and the individuals themselves who consider whether to pursue doctorate studies and proceed with research or unrelated careers. This paper provides an overview of the key statistical and analytical findings that draw on data from the second international CDH data collection conducted in 2010, as well as some complementary sources. Box 1 provides further details on this project.

The opinions expressed in this paper are the sole responsibility of the authors and do not necessarily reflect those of the OECD or those of its member countries' governments.

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4.2 Increased Flows of New Graduates Raise the Share of Doctorates in the Population

The past decade has witnessed the continued development of higher education and research systems worldwide. The expansion of higher education has resulted in not only a massive increase of tertiary level graduates but also marked increases in the number of individuals with postgraduate degrees, including doctorate awards. In 2009, around 213,000 new doctoral graduates graduated from universities in OECD countries, an increase of 38 % with respect to the 154,000 who graduated in 2000. Figure 4.1 shows that nearly 1.5 % of individuals in a comparable age cohort received a doctoral degree, a figure as high as 3.4 % in Switzerland and 3 % in Sweden. The increasing presence of women in doctoral programs partly explains the overall increase in doctorates over the past decade. Women were awarded on average almost half (46 %) of OECD's new doctorate degrees.

Box 1

The Careers of Doctorate Holders Project

Evidence gaps and the development of a dedicated global data source on doctorate holders

The OECD, in coordination with the UNESCO Institute for Statistics and Eurostat, launched in 2004 a new project on the Careers of Doctorate Holders (CDH) aimed at addressing evidence gaps on this population which other generic statistical sources were not able to deal with. Methodological guidelines, a model questionnaire and a set of reference output tables (key indicators) were developed for collecting data on doctorate graduates on an international basis (Auriol et al. 2012). A pilot data collection was also conducted involving a reduced number of countries. A first large-scale data collection was launched in 2007 in which 25 countries participated. This collection provided a rich set of data but also highlighted a number of technical challenges, which a further data collection in 2010 sought to address. Belgium, Bulgaria, Croatia, Denmark, Finland, Germany, Hungary, Iceland, Israel, Latvia, Lithuania, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovenia, Spain, Sweden, Switzerland, Chinese Taipei, Turkey and the United States collected information on the situation of doctorate holders as of 1 December 2009.

The CDH-KNOWINNO Project

Over the 2011–2012 biennium, the OECD activity on CDH was partly sponsored by the European Union's Seventh Framework Program as part of the broad OECD KNOWINNO project. This supported the development of the CDH database by the OECD and helped produce a set of internationally-comparable indicators based on the results from the 2010 CDH data collection (Auriol et al. 2013). In order to address a number of policy and analytical

(continued)

questions, four key areas of work were identified for detailed investigation: (1) early career of doctorate holders; (2) job-to-job mobility; (3) international mobility and (4) competences and skills of doctorate holders. With the help of a data coding guide provided by the OECD, ten volunteer countries harmonised their micro data sets in order to implement tabulations and econometric analyses using a common programming code developed by two national participant institutes, i.e. CSIC/Spain and NISTEP/Japan. Each topic was led by a participant organization: NISTEP/Japan for early careers, DGEEC/Portugal for job-to-job mobility, CSIC/Spain for international mobility and ECOOM/University of Ghent/Belgium for competences and skills.

In order to extend the number of countries for which comparisons could be carried out, a special effort was also made to define common populations of doctorate holders among surveys of university graduates available for France, Japan and the United Kingdom, and subsamples within CDH surveys carried out in other countries. Access to and use of micro data was instrumental in facilitating these specific comparisons that were carried out under the "early career module" of the project.

There are rather marked differences in the doctorate intensity of labor markets across countries. The high performance of Switzerland in terms of doctoral training is reflected in estimates of the stock of doctorate holders in the working age population (Fig. 4.2). Luxembourg shows a similar pattern due the presence of a large share of foreign doctoral graduates. Germany, the United States and the United Kingdom also display particularly high shares of doctoral graduates, with

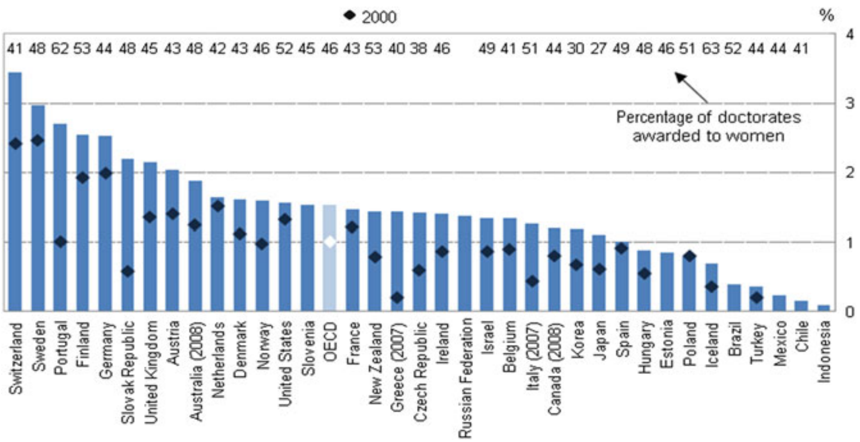

Fig. 4.1 Graduation rates at a doctoral level, 2000 and 2009. As a percentage of population in reference age cohort. *Source*: OECD, Education at a Glance 2011: OECD Indicators and Education at a Glance 2009: OECD Indicators

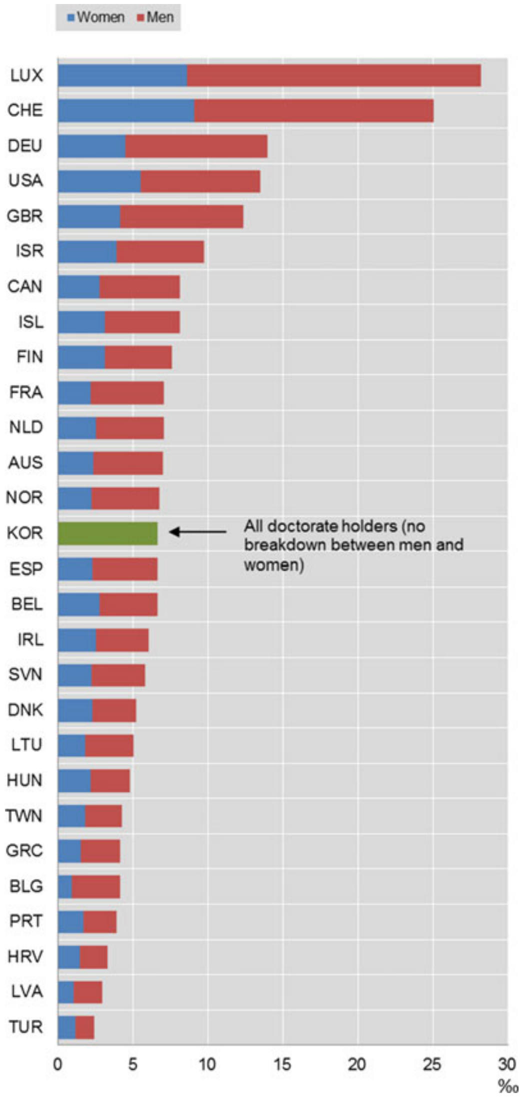

Fig. 4.2 Doctorate holders in the working age population. 2009, per thousand population aged 25–64. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010; OECD Main science and technology indicators; OECD Education attainment database. *Notes*: Data for Chinese Taipei only include those doctorates in the National Profiles of Human Resources in Science and Technology (NPHRST) complied by STPI, NARL, Chinese Taipei: http://hrst.stpi.narl.org.tw/index.htm#noticeChinese. Doctorate holders in the business sector are under-represented

doctorates respectively accounting for 1.4, 1.3 and 1.2 % of the working age population.

4.3 Overall Demand of Doctorates Remains Strong

Despite reported concerns in the media about excessive graduation rates and claims that advanced skills are being underutilised, there is no evidence to suggest that the growth in the number of individuals at the highest level of qualification has resulted in some form of excess supply that the labor market struggles to accommodate. Most indicators point to a sustained, if not increasing premium on doctorate skills, which is consistent with rising demand for individuals with such skills. A considerable body of literature has shown that labor market outcomes improve with the level of education (e.g. OECD 2011). Comparisons between doctorate holders and other individuals at the upper end of the educational attainment distribution should take into account possible differences in competencies and skills that are not attributable to the pursuit of additional education and the role these play in driving education and future labor market participation decisions. Comparing CDH statistics with standard labor force statistics, individuals with doctoral degrees had higher employment rates than the average higher education graduates in 2009 (Fig. 4.3), which confirms the findings based on the first CDH data collection back in 2006, prior to the onset of the economic crisis (Auriol 2010). Due to differences in survey design, comparisons across different data sources should be made with caution and differences may not be as large as implied by the chart. However, this result is replicated across countries with surveys that cover the broad set of higher education graduates. Given the very similar employment rates found for men and women at the doctorate level, there is reason to believe that the "premium" effect is driven by the latter's relatively increased attachment to the labor market.

Labor force survey data for the United States and the United Kingdom allow for comparing doctorates and other education groups across a number of labor market dimensions. These data show that the proportion of doctorate holders in the labor force aged 25 and above increased steadily between 1995 and 2011. Over this period, doctorate holders went from representing 1.3 % of the labor force to 2 % in the United States, and from 0.7 to 1.2 % in the United Kingdom.

Despite this near doubling in the share of the workforce, Fig. 4.4 shows that, in the United States, the earnings premium relative to other postgraduates (which includes masters' graduates and MBAs) increased from 11 % in 1995–2002 to 15 % 2003–2011, and from 28 to 34 % relative to those with bachelor's degrees. The estimated earnings premium in the United Kingdom was lower to start with, especially compared to first degree holders, although the same upward trend is apparent. The estimated premium increased from around 2 to 9 % with respect to other postgraduates, and from 6 to 14 % with respect to first and other degree holders.

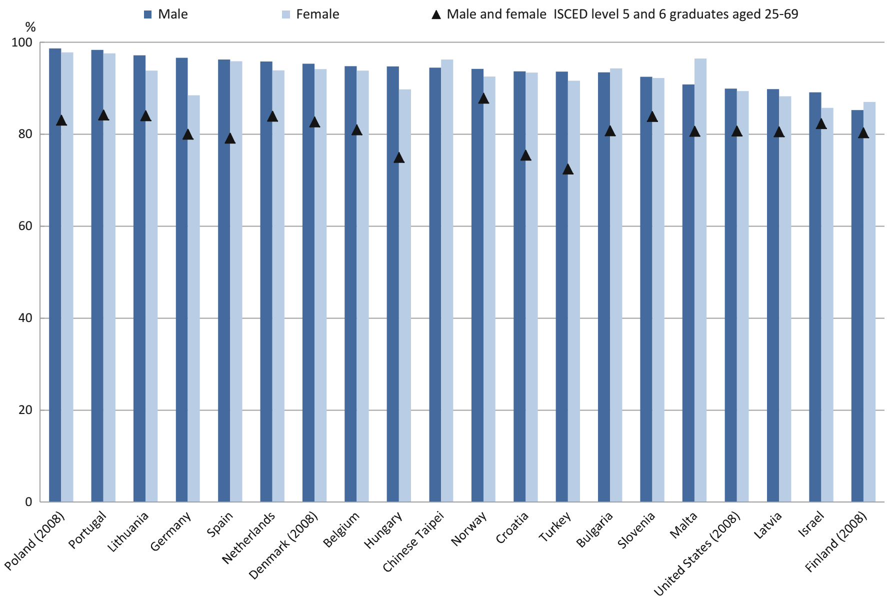

Fig. 4.3 Employment rate of doctorate holders by gender, 2009. As a percentage of total doctorate holders. *Notes*: Data for Belgium, Germany, Hungary, the Netherlands and Spain refer to graduation years 1990 onwards. For Belgium and Malta, data for the 65–69 age class include doctorate holders aged 70 years and above. For Spain, there is limited coverage of doctorate holders for the years 2007–2009. Data for Chinese Taipei only include those PhD in National Profiles of Human Resources in Science and Technology made by STPI, NARL, Chinese Taipei: http://hrst.stpi.narl.org.tw/index.htm#noticeChinese. For the United States, data exclude doctorate holders who received their degree abroad and who received a doctorate in humanities. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010; Eurostat 2012; Education at a Glance 2012

4.4 Higher Education and Academic Careers Are the Main Destination of Doctorate Holders

CDH data indicate that the education sector is indeed the main institutional sector[1] of employment for individuals with a doctorate degree, accounting for a rather variable proportion of doctorates, from around one-third of the total in the Netherlands, Denmark and Belgium, to nearly four-fifths in Poland and Portugal. Government and business sectors alternate as the second most important destination. In Belgium, Denmark and the United States, at least one out of three employed doctorate holders works in the business sector. This sector primarily attracts those

[1] Based on the sectoral classification for R&D performing units in the OECD Frascati Manual (OECD 2002), which includes Higher Education, Business Enterprise, Government and Other Private non-Profit.

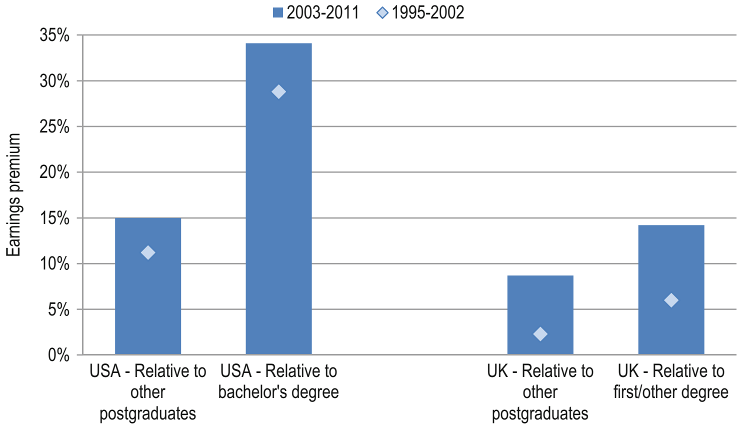

Fig. 4.4 Doctorate wage premium in the United States and the United Kingdom. Estimated differences in log hourly earnings. *Notes*: Based on ordinary least square regressions of log hourly earnings, controlling for other personal and job characteristics. *Source*: OECD calculations based on the US Current Population Survey and the UK Labour Force Survey

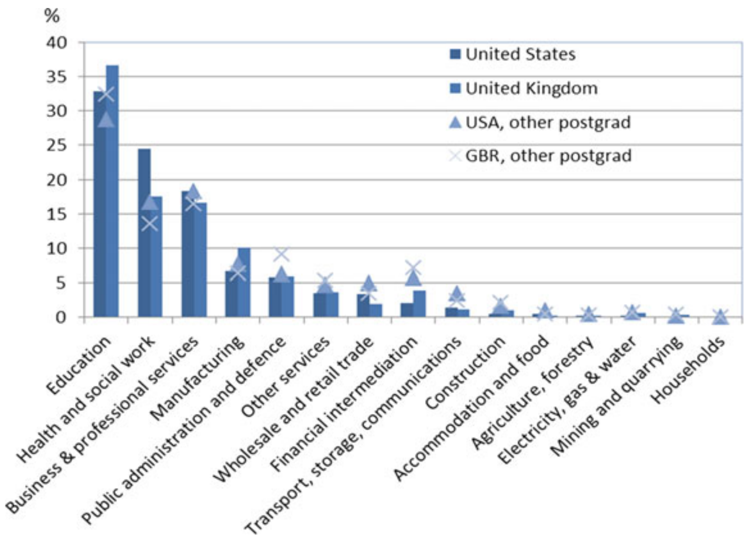

Fig. 4.5 The sector of economic activity for UK and US doctorates, 2003–2011. As a proportion of total doctorates or "other postgraduate" qualification group. *Source*: OECD, estimates based on US Current Population Study and UK Labour Force Survey micro-data

specialised in engineering as well as chemical scientists. The results from early destination surveys of the United Kingdom and Japan indicate a similar pattern.

Detailed breakdowns by main activity, as opposed to a broad, institutional sector, are not yet available for CDH dedicated data but should be in the future following revised guidelines. In the case of the United Kingdom and the United States, labour force survey data (Fig. 4.5) show that the education sector employs above a third of the total population of doctorates, followed by the health and business and professional services sectors. Manufacturing is the fourth largest destination for the doctorate population, followed by public administration. Further analysis shows that doctorates are not only employed in professional but also in management occupations.

4.5 There Exist Potential Challenges for Recent Doctorate Holders

While the situation for doctorate holders looked rather benign in 2009, given the prevalent economic conditions, there is a perception that new cohorts of graduates are facing very different circumstances to those faced by their older peers at similar stages of their careers, raising concerns about what this may imply for motivations to embark on doctoral careers. The available data suggest that the employment rates of recent doctoral graduates were still high compared to the broad population, but less so in some countries. Three years after graduation, the employment rate of doctoral graduates was estimated to be 89 % in 2010 in France. In Israel, the employment rate was 84 % in 2009 for those individuals who received their doctoral degree in the previous 5 years (Fig. 4.6).

These high employment rates, however, may mask relatively precarious working conditions. CDH data confirms that while employment rates may not differ substantially between cohorts of doctorates, temporary contracts are far more prevalent among those who received their degree less than 5 years ago. These figures are relevant to the analysis of the 'postdoc' phenomenon, a hard-to-measure concept in an international context given the diversity of arrangements for positions which are in principle aimed at consolidating or improving the research training of new doctorate recipients and preparing them for a research career.[2] The CDH results may be consistent with claims that young doctoral graduates wishing to pursue academic careers have to undertake an increasing number of postdoctoral positions before achieving a tenured research position at a university or public laboratory.[3] This could lead to concerns about a potential deterrent effect on taking up research careers.

[2] The terms of indefinite contracts differ across countries depending on the existence of employment protection laws.

[3] See for example: http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_07_06/caredit.a1200075

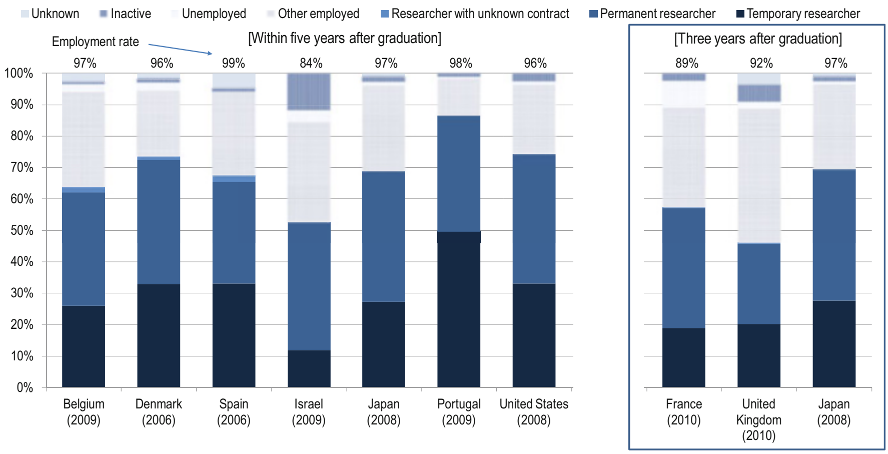

Fig. 4.6 Employment status of recent doctorate graduates, 2009. As a percentage of doctorates who graduated in the previous 5 years, or 3 years after graduation. *Notes*: Only doctorate holders who obtained an advanced degree from the reporting country are considered for better comparability. "Other employed" includes those with unknown research status. For France, only those graduates aged 35 years old or less were surveyed. Data for Japan contain information of all recent doctoral graduates (census) with imputation and some higher education teaching personnel, such as part-time lecturers, are also classified as researchers. Non-EU domiciled students are outside the scope of the survey for the United Kingdom. The research status was derived using a combination of information on employment sector and occupation and is not exactly the same as the *Frascati* definition for the United Kingdom. Data for Belgium and UK data not weighted. *Source*: OECD, based on ad hoc tabulations of data from CDH and early destination surveys (EDS) from France, the United Kingdom and Japan, November 2012

4.6 The Business Sector Offers More Attractive Contractual Arrangements to Recent Doctorates

In most countries, the concern about temporary positions for new doctorates appears to be mostly concentrated within the higher education sector, as seen in Fig. 4.7 below. For the majority of countries, the share of recent doctoral recipients engaged in research in the higher education sector who have permanent/indefinite contracts is below 50 %. The share of researchers with permanent/indefinite contracts in the business sector is higher in all cases and is over 90 % in Belgium, Denmark, France, Japan and the Unites States. This finding could be potentially interpreted as evidence that younger doctorates in the higher education sector are willing to forego some benefits, such as indefinite employment terms, for the prospective opportunity of securing a tenured position and other non-pecuniary benefits, as will be discussed below.

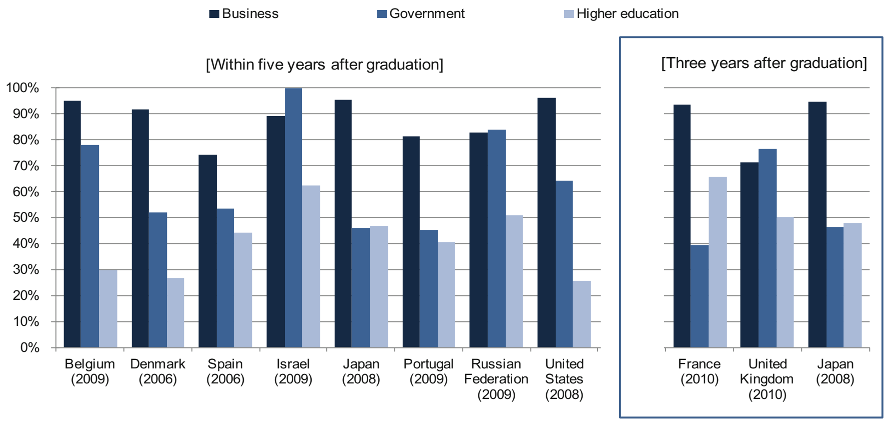

Fig. 4.7 The incidence of indefinite contracts among recent doctoral graduates engaged in research. Percentage with indefinite/permanent contracts, by sector of employment. *Notes*: Estimates calculated for those whose contract types are known. Only doctorate holders who obtained an advanced degree from the reporting country are considered for better comparability. For France, only those graduates aged 35 years old or less were surveyed. For the United Kingdom, the *Frascati*-based sectoral classification has been approximated: all R&D firms are assigned to "business". For Japan, some higher education teaching personnel such as part-time lecturers are also classified as researchers. Non-EU domiciled students are outside the scope of the survey for the United Kingdom. The research status was derived using a combination of information on employment sector and occupation, and the business sector combines 'Finance business and IT', 'Manufacturing', 'R&D' and 'Other sectors' and the government sector corresponds to 'Health and social work' and 'public administration and defense' for the United Kingdom. Belgian and the UK data are not weighted. *Source*: OECD, based on ad hoc tabulations of CDH surveys and early destination surveys (EDS) from France, the United Kingdom and Japan, October 2012

4.7 A Majority of Doctorates Work as Researchers

The structure of labor markets and the organization of research systems have undergone significant changes, which have contributed to traditional linear research career paths giving way to a more diverse range of career experiences. In the run-up to the economic and financial crisis, "job hopping" among the highly skilled had become more common and tenured positions in the academic sector declined in importance relative to temporary ones. With the high growth in new doctoral awards, some observers have wondered whether innovation systems are mature enough to create research positions that fully utilise the skills of the doctorate population. Considering these questions requires a better understanding of

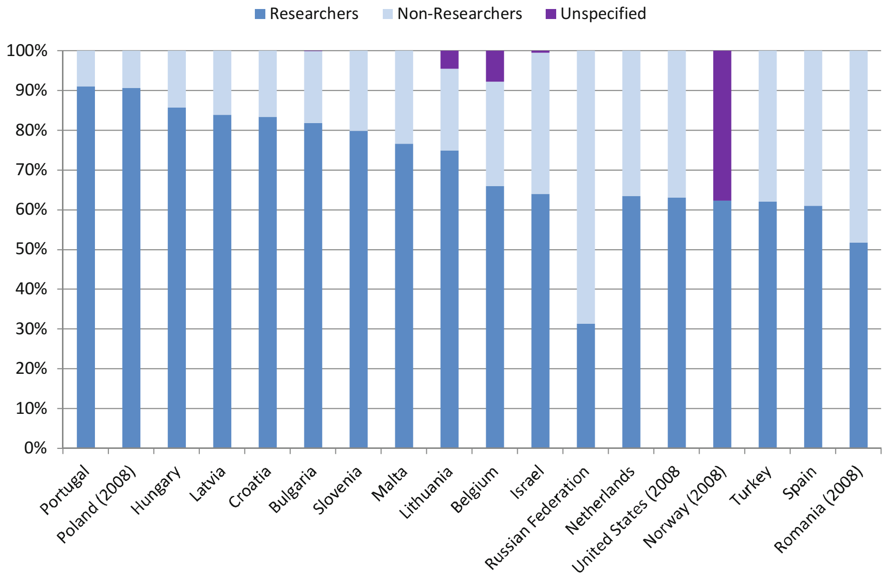

Fig. 4.8 Doctorates employed as researchers. As a percentage of employed doctorate holders. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010. *Notes*: Data for Belgium, Hungary, the Netherlands and Spain refer to graduation years 1990 onwards. For Belgium, Malta and the Russian Federation, data for the 65–69 age class include doctorate holders aged 70 years and above. For Spain, there is limited coverage of doctorate holders for the years 2007–2009. For the United States, data exclude doctorate holders who received their degree abroad and who received a doctorate in humanities

differences between doctorates employed as researchers and those who are not, evaluating for example to what extent occupations are related to the doctoral studies, satisfaction, pay and their evolution in the short to longer term. Across countries for which data are available, at least 50 % of doctorate holders are working in research. In Portugal and Poland, more than 80 % of doctorate holders work as researchers, whereas the shares are lower (close to 60 %) in Belgium, the Netherlands and the United States (Fig. 4.8).

Doctorate holders in the natural sciences and engineering are the most frequently employed as researchers, except in Portugal and Poland where there are no obvious differences across fields and the share of researchers is high. By contrast, large variations across fields of study exist in countries where a non-research career is more common.

Taking into account the various observed factors that relate to the probability of working as a researcher among those individuals in employment, it is apparent that as careers progress after graduation, individuals become more likely to do non-research jobs (Fig. 4.9). In general, the share of research positions is higher

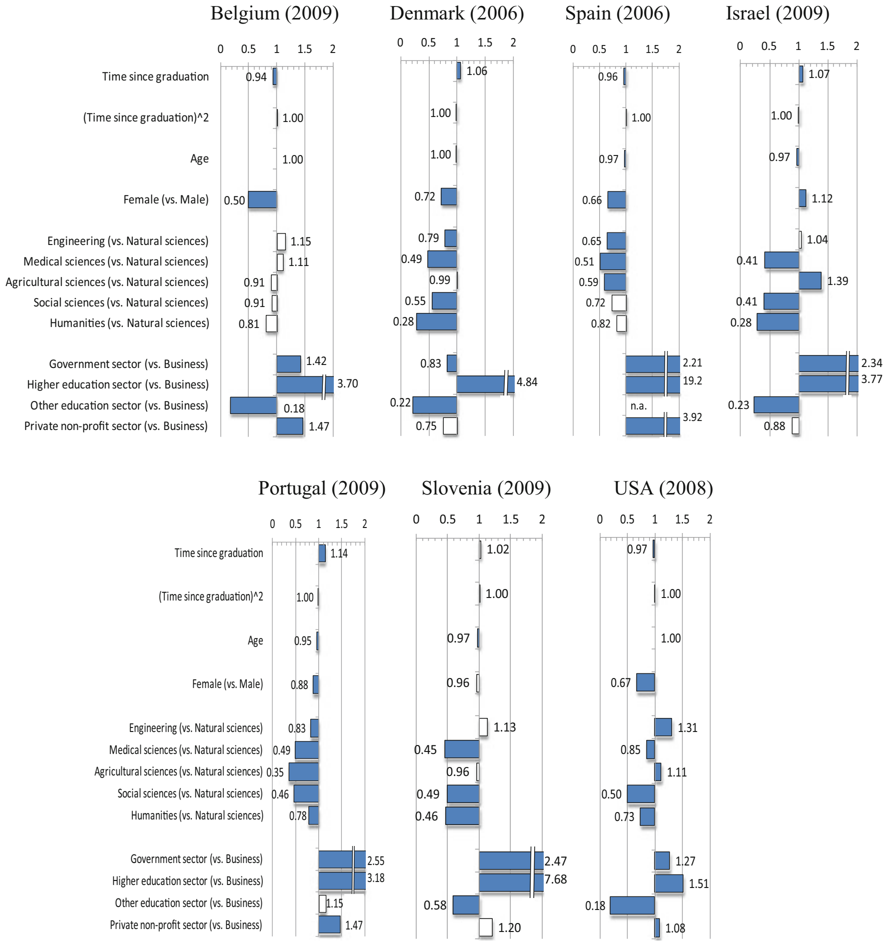

Fig. 4.9 Factors determining the probability of working as a researcher. Odds ratios. *Notes*: The odds ratios from logistic regression analysis are shown and illustrate the odds of corresponding group of being a researcher relative to those of reference group, controlling for the other variables. For instance, for Belgium, the odds of being a researcher among doctorates employed in the higher education sector are 3.70 times higher than for those employed in the business sector. Filled boxes correspond to estimates that are statistically significantly different from one, with p-values less than 5 %. For the United States, most individuals specialised in humanities are outside the scope of the survey. *Source*: OECD, based on ad hoc analysis of CDH micro data, October 2012

for recent doctorate recipients in natural sciences and engineering and lower for those who studied humanities. However, differences by field of study become less marked after controlling for the sector of employment, with only a slight hint that graduates in the natural sciences are more likely to work as researchers. The analysis also confirms that individuals who work in the higher education sector are significantly more likely to work as researchers and that it is individuals in the business sector that are least likely to do so.

4.8 Jobs of Doctorate Holders Relate to Their Studies Even When Not in Research

Female doctorate holders are systematically less likely to work on research, a finding that is also replicated when looking at whether one's job is related to one's doctoral studies, even if it does not involve research. Denmark is a notable exception, with women having just the same probability as men to hold a job related to their field of study. Graduates in the social sciences, although less likely to work as researchers, are the group whose jobs tend to be the most closely related to their study topic. This suggests that skills and knowledge acquired through doctorate studies are used for activities other than research (Fig. 4.10).

4.9 Job Mobility Patterns Differ Markedly Across Countries

CDH data can be used to document the mobility of individuals with doctorate degrees, a priority question from the perspective of sponsors of PhD programs whose objective is to maximise the social and economic benefit of their public investment in training researchers. Voluntary mobility can be expected to improve the quality of the match between doctorates and employment and promote knowledge transfer. However, mobility may also be the outcome of unintended separations and represent the breakdown of a stable match, for example as a result of a business closure, or reflect career instability and low attachment.

CDH data show that, on average, one out of four doctorate holders have changed jobs over the past 10 years. Doctorate holders from Denmark, Poland, Netherlands, Israel and Slovenia rank amongst the most mobile, and Belgium, Russian Federation and Spain amongst the least mobile. Doctorate holders who work as researchers are found to have been less mobile than their counterparts who do other types of jobs (Fig. 4.11). As careers progress and available opportunities, circumstances and personal preferences change, individuals are likely to drift away from research into other types of occupations. For those doctorate holders who have changed jobs, the evidence points to major differences in the nature of job moves across countries.

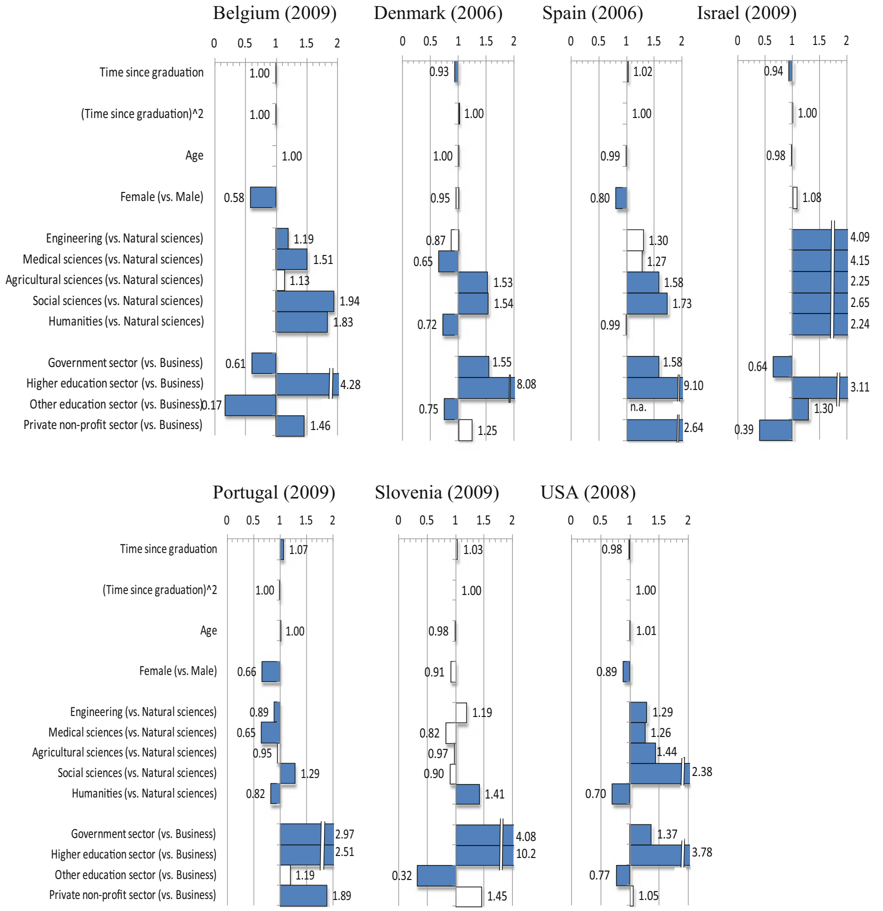

Fig. 4.10 Factors determining the probability of holding a job related to doctoral study. Odds ratios. *Notes*: Based on answers to question: "To what extent was your work on your principal job held on 1 December 2009 related to your advanced research qualification degree?" The odds ratios from logistic regression analysis are shown and illustrate the odds of corresponding group of holding a job related to doctoral study relative to those of reference group after controlling for other variables. For instance, the odds of social scientists getting a job related to doctoral study are 2.38 times higher than natural scientists in the United States. *Filled boxes* correspond to estimates that are statistically significantly different from one, with p-values less than 5 %. For the United States, most of those specialized in the humanities are outside the scope of the survey. *Source*: OECD, based on ad hoc analysis using the CDH micro data, October 2012

Although most mobility occurs within sectors, among job movers, this is far more likely to be the case in countries like Belgium and the United States than in others like Spain and Portugal, particularly outside the higher education sector (Fig. 4.12). Mobility also appears to be more prominent from the business

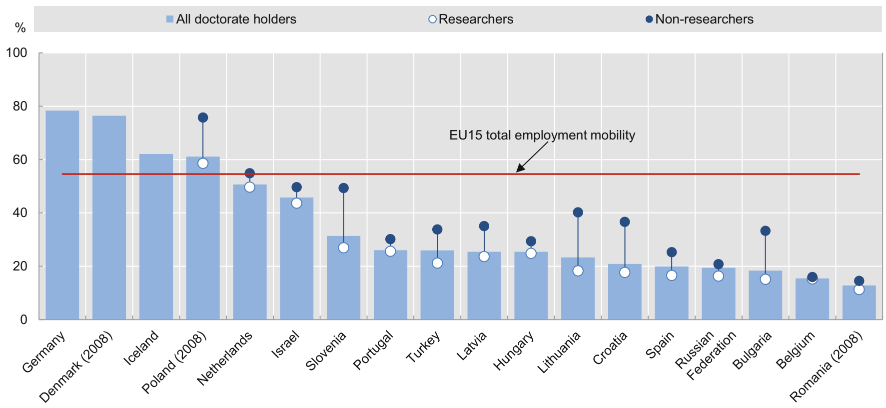

Fig. 4.11 Job mobility of doctorate holders. Percentage of doctorate holders who changed jobs in the last 10 years, 2009. *Notes*: Data for Belgium, Germany, Hungary, the Netherlands and Spain refer to graduation years 1990 onwards. For the Russian Federation, data relate only to those doctoral graduates employed as researchers and teachers. For Spain, there is limited coverage of individuals who graduated between 2007 and 2009. EU15 total employment mobility is computed on the basis of the OECD Job Tenure Database and corresponds to the share of 25–69 year-old employed individuals who have changed jobs in the last 10 years. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

enterprise sector to the higher education than the other way around, with the exception of the United States and the Netherlands.

4.10 Earnings Differences Vary Across Countries and According to Individual and Job Characteristics

The expected level of earnings may be a key determinant in the choice of a particular career path prior to and after completing doctoral studies. Earnings differentials between sectors of employment and between countries may also influence preferences for specific occupations or where to reside.

Data on earnings show that wide variations exist in the level of median gross annual earnings of doctorate holders across countries, ranging from 18,306 US dollar PPPs in the Russian Federation to 93,000 in the United States, i.e. a factor of 1–5. The least paid doctorate holders can be found in Central and Eastern European countries (with the exception of Slovenia), while the highest median gross annual earnings are found in the United States and the Netherlands (Fig. 4.13).[4] International differences can be expected to act as drivers of international mobility.

[4] These headline figures are not adjusted by differences in hours worked, which could push down the average earnings for countries with higher shares of part-time employees, nor differences in the experience or skills of the doctorate population.

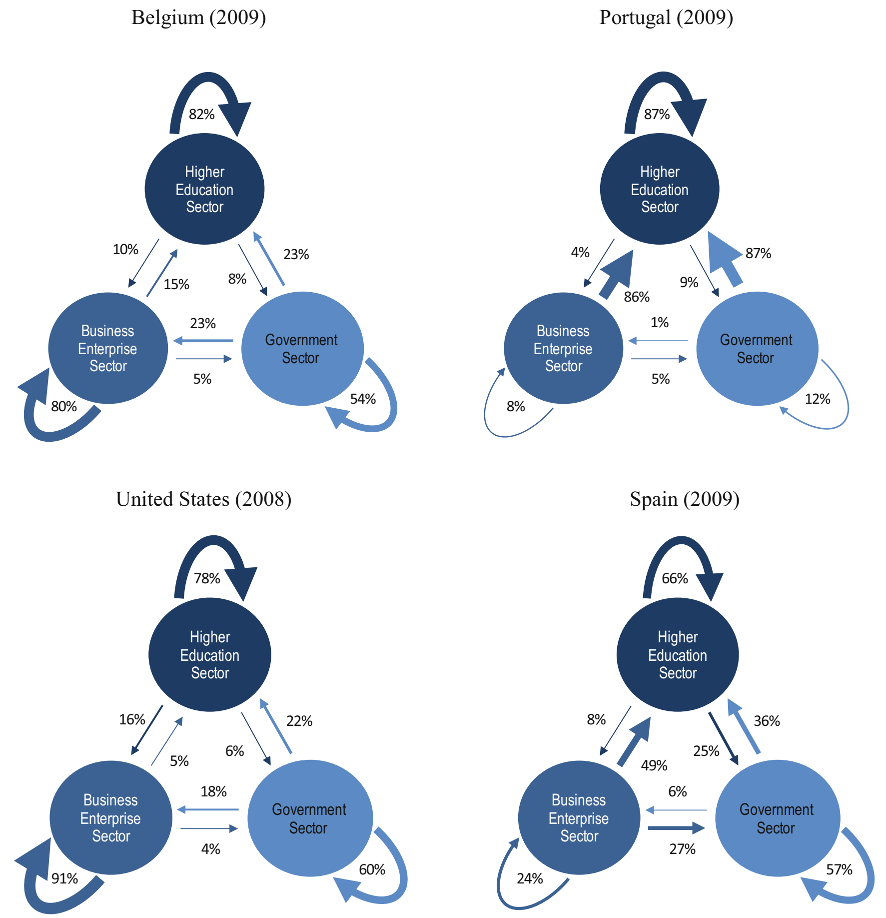

Fig. 4.12 Patterns of past job mobility of doctorate holders working as researchers, by sector of activity. Percentage of intra and inter-sectoral job moves, for those having moved jobs in last 10 years. *Notes*: For the United States, as a proportion of job moves in the previous 2 years. Inter- and intra-sectoral mobility rates are calculated for those engaged in research activity in December 2009 and employed in three main sectors at both periods (current and previous employment). Job moves within sector and flows out of one's sector add up to 100 %. *Source*: OECD, based on DGEEC calculations using CDH OUTPUT tables, October 2012

CDH statistics also show that women earn less than men and in some countries the difference is close to or above 25 %. At the sectoral level, the difference between male and female median gross annual earnings is most marked in the business enterprise and government sectors. The differential exceeds 20 % for the Netherlands Turkey, Bulgaria, Hungary, Slovenia, Malta and Portugal in the business enterprise sector, and Latvia, the Netherlands, Lithuania, Russian Federation and Malta in the government sector. These earnings differences become smaller but

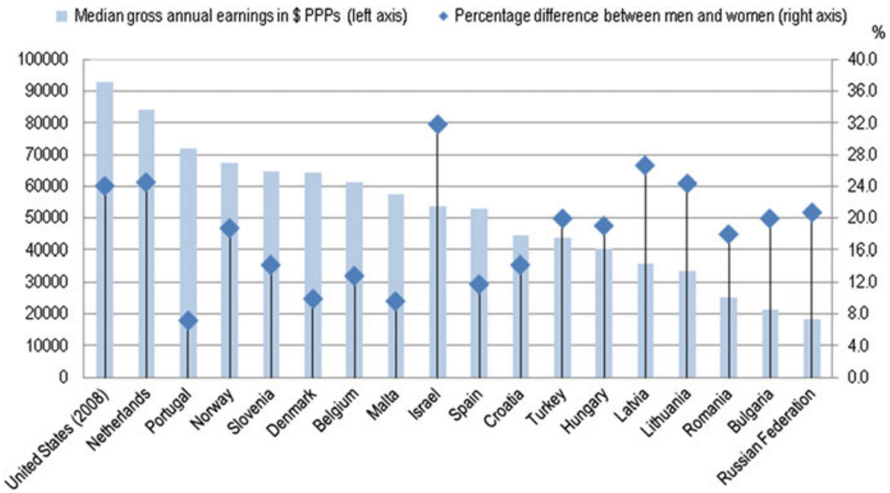

Fig. 4.13 Median gross annual earnings of doctorate holders. USD PPPs, 2009. *Notes*: Figures are in US dollars adjusted for differences in purchasing power (parity) (PPP). Data for Hungary, the Netherlands and Spain refer to graduation years 1990 onwards. For the Russian Federation, data relate only to those doctoral graduates employed as researchers and teachers. In this case, earnings for doctorates working as managers would be excluded for example. For Spain, there is limited coverage of doctorate holders who graduated between 2007 and 2009. Data for the United States exclude doctorate holders who received degree abroad and who received a doctorate in humanities. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

remain statistically significant after controlling for observable characteristics, as revealed by the coefficient on female doctorate holders in Fig. 4.14.

A number of regularities have been identified in the data, both in descriptive statistics and through regression analysis carried out for selected countries (Fig. 4.14), controlling simultaneously for a wide range of individual and job characteristics, including time elapsed since graduation. Gross annual earnings of doctorate holders employed as researchers systematically exceed those of non-researchers, although this "premium" varies across countries. For example, the United States and Belgium appear to place a higher premium on being a researcher than Spain and Portugal. Conforming to expectations, doctoral researchers are typically better paid in the business sector than in higher education. After controlling for other characteristics, the gap is nearly 25 % for the United States, a country where academic pay is considered to be large, while in Spain and Portugal, pay appears to be higher in the higher education sector. This would be consistent with the earlier findings concerning inter-sectoral mobility into the higher education sector. Further analysis would be required to understand whether the public sector pay levels are leading to crowding-out or whether demand for doctorates in their business sector lags the demand levels found in other countries.

There are also variations by fields of science. For example, median earnings of doctoral graduates in agricultural sciences and humanities are below the overall

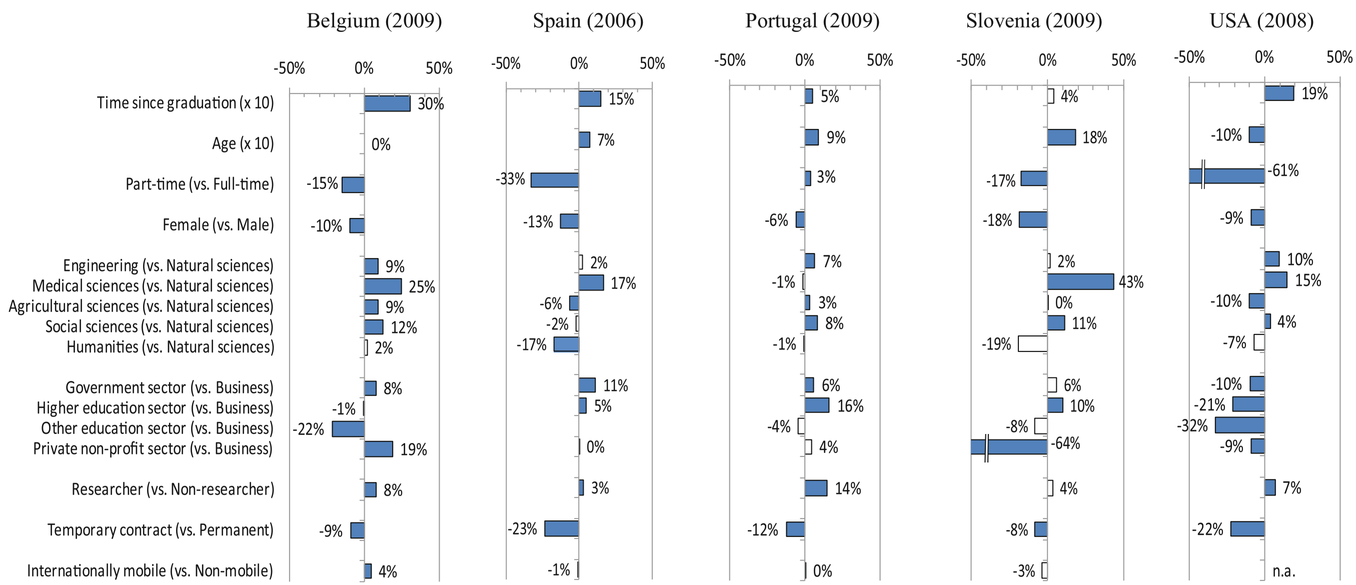

Fig. 4.14 Differences in annual earnings. Estimated coefficients from regressions of log earnings (i.e. percentage differences). *Notes*: Results based on ordinary least square regressions of log annual earnings on individual and job characteristics. *Filled boxes* correspond to statistically significant estimates with p-values less than 0.05. For the United States, most of those specialised in humanities are outside the scope of the survey. *Source*: OECD, based on analysis of CDH micro data, November 2012

median in most countries, whereas doctorate holders in medical and health sciences are generally paid above the overall median. As expected, doctoral graduates in part-time and temporary positions are likely to earn less than those who have indefinite/permanent contracts.

The experience of international mobility appears to be positively associated with higher earnings in the case of Belgium, while that is not the case of Spain and Portugal. This lack of an effect is surprising after controlling for other factors, as it reveals that the investment in international mobility are not compensated by higher pay in these countries.

4.11 International Mobility of Doctorate Holders Has Been Increasing but Remains Low

In a world in which research is carried out on a global basis and personal transport is more affordable than ever, it might be expected that most researcher doctorates should have been exposed to an episode of international mobility in order to draw upon the expertise at leading research organizations.[5] The United States continues to be a major focus of attraction for internationally mobile doctorate holders. This country has been for several decades a magnet for the research community worldwide, offering particularly attractive infrastructure and working conditions. Complementary data on migration to the United States reveal that there were around 610,000 foreign-born doctorate holders in this country in 2005–2009 representing 27 % of the total population of doctorate holders and an increase of 38 % compared to 2000. Half of these were born in Asia and 28 % in Europe. Close to 100,000 doctorate holders were born in China, of which 40 % have US citizenship. The Russian Federation, Bulgaria, Australia and New Zealand have seen the number of their native citizens acquiring US citizenship double over this period. The share of native-born who acquired US citizenship has remained stable for Canada, Germany and South Africa and has decreased for two out of five countries, indicating that doctorate holders originating from these countries come essentially for temporary mobility reasons.

CDH data reveal that, on average, 14 % of national citizens with a doctorate degree have had at least one experience of international mobility of 3 months or longer over the previous 10 years. Individuals in countries that host world-leading research organizations may perceive a lesser need to move abroad. However, a number of barriers, including economic and personal costs, language differences and lack of incentives may explain this apparently low mobility rate.

The main destinations reported in the data refer to the United States and large European countries as the main destinations of internationally mobile doctorate holders. In most cases, this mobility has been a "one-off" event. CDH data show

[5] A recent OECD report shows that one third of all recent immigrants to the OECD were tertiary-educated: http://www.oecd.org/migration/49205584.pdf (Widmaier and Dumont 2011).

that academic reasons are typically cited as the main reason for having gone abroad. Results from the analysis of CDH micro-data show that, for Belgium, Portugal, Spain and the Russian Federation, doctorate holders employed in the higher education sector, those engaged in research, those specialised in natural sciences and those with temporary contracts exhibit the highest levels of international mobility. The same holds true for those who recently received their doctoral degree, except in the cases of the Russian Federation and Spain.

Further evidence is needed to understand the relationship between career promotion and international mobility, for example the extent to which academic tenure decision processes encourage mobility. Mobility can have personal, economic and transaction costs which should be in principle compensated by improved career prospects from increased interaction with centres of research excellence found elsewhere, but mechanisms may not be in place to fully facilitate the exploitation of the benefits of mobility. For example, by moving abroad, individuals may lose the right to opt for jobs in their home institutions, relative to those who stay. Some institutions address this problem by precluding the hiring of incumbents or by including the requirement of mobility as a requirement for hiring.

CDH data from Belgium indicate that international mobility experience is related to the propensity to engage in international research collaboration. Unfortunately, this finding cannot currently be corroborated for other countries but could be evaluated in the future by (confidentially) linking survey and scientific publication data for researcher doctorates.

4.12 International Mobility Begets Further Mobility, and Is Primarily Intended for a Limited Period of Time

Micro data analysis shows that, across all countries for which data are available, temporary contract holders are more likely to report an intention to move abroad (Fig. 4.15). Interestingly, it appears that those with past mobility experience are more likely to consider going abroad another time, which could indicate an idiosyncratic preference for mobility within this group, or the possibility that a prior experience demonstrates benefits of mobility. This finding is consistently found for all countries for which data are available, it applies to those on temporary and permanent contracts and it is confirmed by multivariate analysis, controlling for other personal characteristics.

In Belgium, Portugal and Spain, these results also show that the likelihood of reporting an intention to move abroad is higher for men and recent doctorate graduates. In Portugal and Spain, intentions to move abroad diminish when income levels increase, potentially reflecting a higher opportunity cost of mobility. In general, the share of doctorate holders planning to move abroad on a temporary basis is higher than that of those planning to move out permanently, which is another indication of the temporary aspect of international mobility.

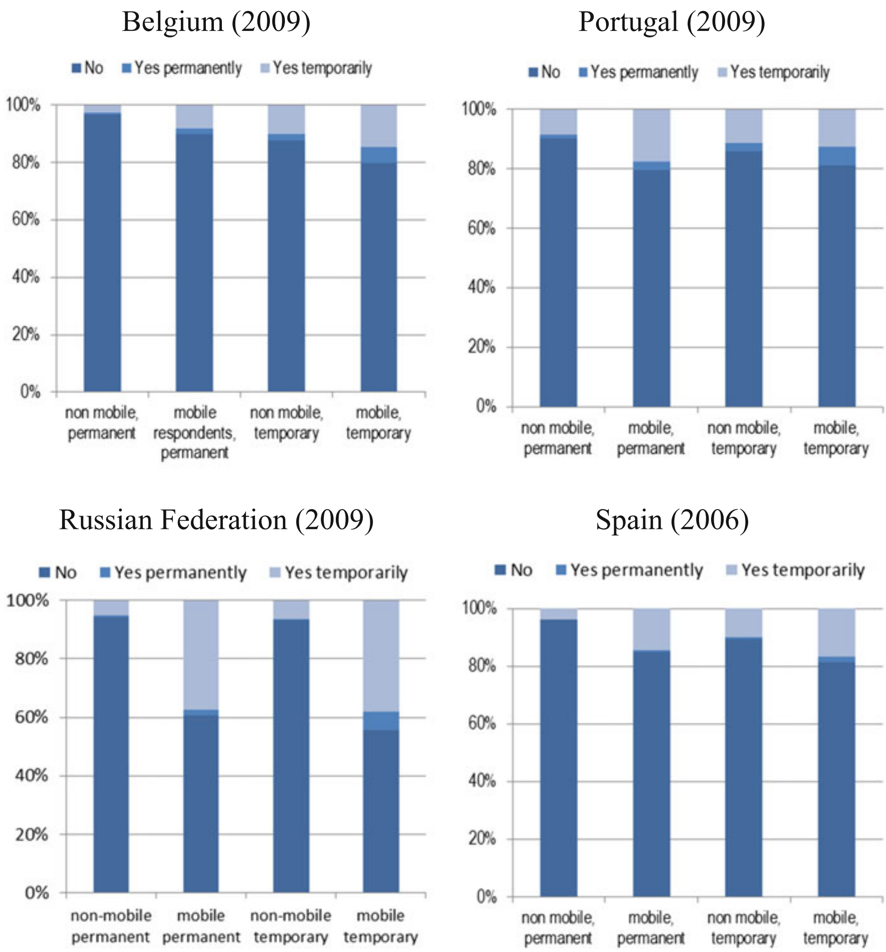

Fig. 4.15 Doctorate holders' intentions to move abroad in the following year. Percentage intending to move, by past mobility and type of contract. *Notes*: Data for Belgium and Spain refer to graduation years 1990 onwards. For the Russian Federation, data relate only to those doctoral graduates employed as researchers and teachers. For Spain, there is limited coverage of doctorate holders who graduated between 2007 and 2009. *Source*: OECD and CSIC, Spain, based on ad hoc tabulations from careers of doctorate holders surveys, November 2012

4.13 Doctoral Graduates Are Generally Satisfied with Their Employment Situation

In addition to previously-reported information on salaries, research occupations and relatedness to study, responses to CDH survey questions on job perception and satisfaction can also be used to evaluate how the experiences of doctoral graduates differ according to personal and job characteristics. Overall, doctorate holders are satisfied with their employment situation. Satisfaction levels with intellectual challenges and with opportunities for advancement are markedly higher for those working as researchers. On the other hand, satisfaction levels with regards to salaries and benefits are lower than with other criteria, suggesting that a significant number of doctorate holders are foregoing some economic benefits in return for doing jobs they find otherwise more rewarding.

4.14 The Research Skills of Doctorate Holders Are Those most Valued on the Labor Market

In Belgium, an additional module on researchers' competencies was added to the standard CDH questionnaire and its findings were compared to different kinds of data collected elsewhere in OECD countries. The results confirm the findings of other studies: assets directly related to research rank high, as do self-management skills and personal attitudes such as working independently, taking initiative and being eager to learn. Possible explanations for the discrepancy between what PhD graduates learned during the doctoral program and their experience in the job were addressed. PhD graduates in Belgium from various disciplines and employed in sectors in or outside academia perceived their experiences and needs differently. Perhaps surprisingly, the type of competencies identified by doctorate holders as highly required in their jobs, does not differ very much across sectors of employment, in particular not when asked about team skills, communication skills and personal effectiveness. The largest variation between sectors can be observed in management skills, which seem to be most important in industry. With regard to research skills, the demands of a university environment are obviously larger than those in other sectors.

4.15 Concluding Remarks

The CDH initiative has been continuously evolving and learning from previous experiences over its relatively short history. The present analysis has at the same time confirmed a number of findings from the previous CDH data collection and shed light on new ones. Most importantly, the results presented in this document showcase the potential of CDH data to inform policy questions that bear on the labor market and the careers of doctorate holders and researchers. Throughout the project, a number of topics have raised particular interest among the participating research teams, pointing to future areas of survey development for testing. Indeed, the changing economic environment, the increasing diversity of career patterns and the changes in the organization of the research landscape may require the use of a different and broader set of skills. This dimension needs to be measured and analysed with the appropriate tools. The revised methodological guidelines and model questionnaire include proposals for capturing information that is relevant to these questions. CDH data can also provide a useful tool for analysing the contribution of doctorate holders to entrepreneurship. There is increased interest in the phenomenon of academic entrepreneurship; and observers have also noted the importance of doctorate training for individuals who started, but never completed their doctoral studies as they chose to develop their inventions by starting up new businesses. The next data collection efforts should help shedding light on these new areas of interest.

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References

Auriol L (2010) Careers of doctorate holders: employment and mobility patterns. OECD Science, Technology and Industry working papers 2010/04. OECD Publishing, Paris. http://dx.doi.org/10.1787/5kmh8phxvvf5-en

Auriol L, Schaaper M, Felix B (2012) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators, 3rd edn. OECD Science, Technology and Industry working papers 2012/07. OECD Publishing, Paris. doi:10.1787/5k4dnq2h4n5c-en

Auriol L, Misu M, Freeman RA (2013) Careers of doctorate holders: analysis of labour market and mobility indicators. OECD Science, Technology and Industry Indicators working papers 2013/04. OECD Publishing, Paris. doi: 10.1787/5k43nxgs289w-en

OECD (2002) Proposed standard practice for surveys on research and experimental development, Frascati manual. OECD, Paris

OECD (2010) Skills for innovation and research, OECD innovation strategy. OECD, Paris

OECD (2011) Education at a glance 2011: OECD indicators. OECD, Paris

Widmaier S, Dumont J-C (2011) Are recent immigrants different? A new profile of immigrants in the OECD based on DIOC 2005/06. OECD Social, Employment and Migration working papers 126, Directorate for Employment, Labour and Social Affairs. OECD Publishing, Paris. http://dx.doi.org/10.1787/5kg3ml17nps4-en

Part II

Doctorate Holders: Employment Outcome and Mobility

Science and Engineering Labor Force in the US

5

Steven Proudfoot and Thomas B. Hoffer

5.1 Introduction

"Graduate education in science and engineering (S&E) contributes to global competitiveness, producing the highly skilled workers of the future and the research needed for a knowledge-based economy," asserts the *2014 Science and Engineering Indicators* report, published by the US National Science Foundation (NSF) (National Science Foundation 2014, Chap. 3). In 2010, the most recent year for which cross-national data are available, more than 200,000 S&E doctoral degrees were earned worldwide. The United States awarded the largest number of S&E doctoral degrees of any country (about 33,000), followed by China (about 31,000), Russia (almost 16,000), Germany (about 12,000), and the United Kingdom (about 11,000). About 58,000 S&E doctoral degrees were earned in the European Union (National Science Foundation 2014, Chap. 2).

The past two decades have been a time of expansion for doctoral education in the US, particularly for doctorates in science, engineering, and health (SEH) fields. This period also coincided with increased mobility of doctoral students internationally, leading to competition among countries' institutions to attract them. While the US-based doctoral education retained a significant "comparative advantage" in attracting non-US born SEH scholars throughout this period, that advantage may not persist. Educational authorities in China, India, and South Korea—to name a few—are today reshaping doctoral education to increase the number of scientists

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and engineers matriculating from their institutions.[1] Finally, the 20-year period ending in 2013 saw the full-fledged emergence of the Internet-networked economy that put a premium on the development of a labor force trained in science, technology, engineering, and mathematics (STEM). US policymakers continue to stress the importance of a STEM-trained workforce, urging a number of initiatives to improve STEM postsecondary teaching (PCAST 2012).

This chapter provides an overview of the US doctoral labor force and how it has changed over the past two decades. The first sections consider the "production" of SEH doctorates leaving the US higher education system and joining the labor force. Over the 20-year span from 1993 to 2013, the growth of the US-trained doctorate population was mainly from two groups: women and non-US citizens.

The next sections examine trends across and within economic sectors. For the academic sector, the most prevalent source of employment for US-trained SEH doctorate holders, consideration is given to 2-year and 4-year higher education institutions, medical schools, and university-based research institutes. The 20-year trends for this sector suggest remarkable stability in employment and employment patterns. For the business sector, factors such as work activities, employer size, and research and development (R&D) activity are considered. A snapshot of this workforce at points in time (1993, 2003, 2013) suggests that more senior scientists than recent doctoral graduates work in non-science and engineering occupations. Over the last two decades there has also been a marked increase in reported self-employment among US-trained SEH doctorate holders.

Much of the data in this chapter is from NSF's Survey of Doctorate Recipients (SDR), which covers the population of SEH research doctorate recipients who received their degrees from US institutions. The SDR, a sample survey of this population, has been conducted biennially since 1973 and includes individuals up to the age of 75. Every 2 years, a sample of new SEH doctoral degree earners is added to the SDR sampling frame from another federally sponsored survey, the Survey of Earned Doctorates (SED), which is a census of research doctorate recipients from US universities. It should be emphasized that the SDR covers the population of SEH *research doctorate* recipients from US institutions. It does not include individuals who earned a doctorate degree outside the US, unless they also received a doctorate in an SEH field from a US institution. Data from the 2010 (the most recent available) NSF National Survey of College Graduates (NSCG) indicate that there were approximately 144,700 employed individuals who reported an S&E doctorate as their highest degree earned and having earned it outside the U.S. From the NSCG database, this represented 15.5 % of all employed S&E doctorate holders in the US in 2010.

The following are the fields represented in the SDR and the percentages of the doctoral SEH workforce in 2013:

[1] For further discussion of these trends, see the section on "International S&E Higher Education" in (National Science Foundation 2014, Chap. 2). http://www.nsf.gov/statistics/seind14/index.cfm/chapter-2/c2s4.htm

- Sciences (76 %)
  - Biological, Agricultural, and Environmental Life Sciences (25 %)
  - Computer and Information Sciences (3 %)
  - Mathematics and Statistics (5 %)
  - Physical Sciences: Chemistry, Physics and Astronomy, Earth, Ocean and Atmospheric Sciences (17 %)
  - Psychology (15 %)
  - Social Sciences: Economics, Anthropology, Archeology, Sociology, Other Social Sciences (12 %)
- Engineering: Electrical, Electronics and Computer Engineering, and Other Engineering fields (19 %)
- Health Sciences (5 %)

5.2 The US SEH Doctoral Population and Its Participation in the US Labor Force

Two major goals the US government enunciated when establishing the National Science Foundation in 1950 were:

1) to evaluate the status and needs of the various sciences and fields of engineering; and
2) to provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and engineering resources and to provide a source of information for policy formulation by other agencies of the Federal Government, by individuals, and by public and private research groups.

In fulfilling these goals, the SED and the SDR play critical roles in determining the numbers of scientists and engineers present in the workforce, the available numbers of individuals who have recently received doctoral degrees in an SEH field, and those with SEH degrees not currently employed in an SEH occupation.

The number of SEH doctorates awarded each year in the United States has increased over the last 20 years. The SED recorded 26,876 SEH doctorates earned from US educational institutions in 1993, increasing by less than 1 % to 27,107 in 2003 and then by more than 45 % to 39,406 in 2013, the most recent data available (National Science Foundation 2015).

The numbers of S&E doctorates increased across all broad fields of doctoral study between 1993 and 2013, with the greatest extent of this change occurring between 2003 and 2013. Only three fields saw an overall increase in the number of doctorates conferred annually between 1993 and 2003. During these years, the population of doctorates earned in the combined biological, agricultural, and environmental sciences, as well as in the social sciences, increased by 10 % each. The number of health doctorate recipients exhibited the largest increase (36 %) between 1993 and 2003. The number of doctorate recipients in the fields of computer/information sciences, mathematics/statistics, physical sciences, psychology, and engineering each showed little change or declined between 1993 and 2003. The increases in the "pipeline" of doctoral graduates into the workforce brought increasing participation of women into the ranks of doctoral scientists and engineers. From 1993 to 2003, the percentage of SEH doctorates earned by women increased from 33 % of all doctorates to 43 % of all doctorates. The annual number of women receiving SEH research doctorates was nearly twice as high in 2013 compared to 1993, while that of men receiving SEH research doctorates was 25 % larger in 2013 than 1993. In sum, the 20-year period of 1993–2013 observed a marked increase in the number and proportional representation of female doctorates in science, engineering, and health fields (National Science Foundation 2015).

Overall, the number of US citizens earning doctorates decreased between 1993 and 2003, but then increased from 2003 to 2013. The number of US citizens earning SEH doctorate degrees increased by about 39 % over the past two decades between 1993 and 2013. In the same 20-year period, the number of SEH doctorates granted to non-US citizens on temporary visas increased by 61 % (National Science Foundation 2015).

5.3 Trends in Employment Outcomes

5.3.1 Labor Force Participation

As SDR data have demonstrated over the years, a doctoral degree in an SEH field is a sound investment for an individual's employability. The SEH doctorate recipient population in the US has an extremely high rate of labor force participation and a low rate of unemployment. Between 2001 and 2013, U.S.-based SEH doctorate recipients experienced very low rates of unemployment, varying from 1.3 to 2.4 % (See Selfa and Proudfoot 2014). SEH doctorates' rates of labor force participation have been consistently close to 100 % up to about age 60, at which point they decline. Nevertheless, seven out of 10 doctorate holders aged 55–75 remain in the labor force, with only about three or four in 10 of the oldest group (ages 70–75) participating in the labor force. As the trend lines show, there is some indication that SEH doctorate holders were remaining in the labor force longer in 2013 than was the case in 1993 (Fig. 5.1).

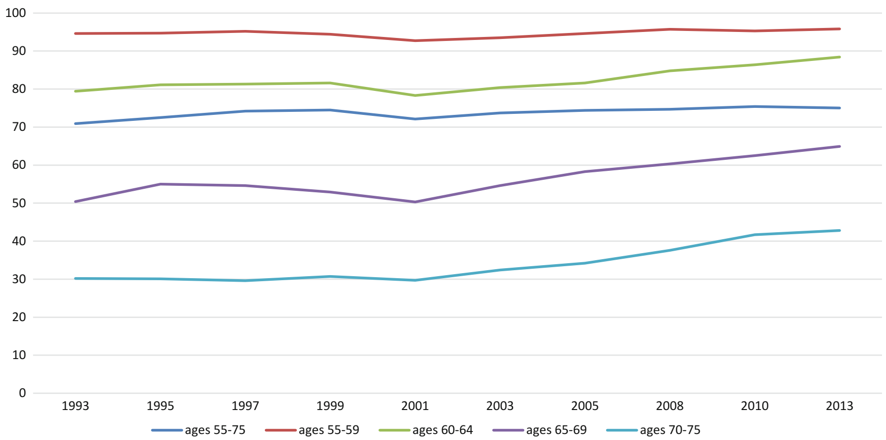

Fig. 5.1 Labor force participation rate of US doctorate holders, by age, 1993–2003

5.3.2 Changes Across Economic Sectors

Doctoral scientists and engineers can be found across the spectrum of employment sectors in the US. In 2013, academe represented the largest employment sector of SEH doctorate holders (44 %), followed closely by business (38 %). Employment of SEH doctorate holders within the government, nonprofits, and the elementary and secondary (K-12) education sectors was much less common (9 %, 6 %, and 2 %, respectively in 2013). There were no changes in the employment of SEH doctorate holders across economic sectors over time, as the percentage of SEH doctorate holders employed in the academic, business, government, nonprofits, and K-12 education sectors remained steady from 1993 to 2003 to 2013 (Table 5.1).

This overall stability in employment by sector, however, overlaid significant changes in the sectorial employment "destinations" of doctorates from specific fields of degree. Between 1993 and 2013, the proportions of doctorate recipients in the fields of computer/information sciences, mathematics/statistics, and engineering working in academe dropped by 7 to 9 percentage points, while the proportions in mathematics/statistics and engineering working in business increased by 5 to 6 percentage points. Doctorate recipients in the field of health showed an opposite trend (SESTAT Data Tool 2016)[2].

The volume of research and development activities scientists and engineers perform, as well as the amount of funding for such activities, are indicators of the country's commitment to further scientific achievement. In all but one sector, the majority of SEH doctorates working in the US in 2013 worked as researchers. Overall, 61 % of the doctorate holders in 2013 reported their primary or secondary work activities as basic research, applied research, development, or design (taken together and collectively referred to as "R&D"). About 65 % of the doctorate holders employed in academe in 2013 worked in R&D, as were similar percentages of those employed in the business (60 %), government (62 %), and nonprofit (58 %) sectors. In the relatively small K-12 education sector, only 26 % worked in R&D in 2013 (Appendix Table 5.6).

5.3.3 Changes by Gender

In the past two decades, female SEH doctorate holders markedly increased their representation across all sectors of employment. This trend applied across the US labor force, and is not limited solely to SEH-related occupations. The percentage of employed SEH doctorate holders who were female increased from 20 % in 1993 to 27 % in 2003 to 33 % in 2013. According to the US Census Bureau's American Community Survey, the US population, aged 25–75, in 2013 was approximately 193.3 million, with 98.6 million (or 51 % of the total) of those

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[2] The statistics cited here and in subsequent places in this chapter where this website is referenced could not be included because of space limitations. However, the data from the 2013, 2003, and 1993 SDR cycles used to calculate these statistics are available to the public from the NSF-National Center for Science and Engineering Statistics (NCSES) at http://ncsesdata.nsf.gov/datadownload/

Table 5.1 Employed S&E doctorate-holders by broad employment sector: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All employed	462,900	484,800	518,400	553,400	574,900	593,300	621,600	651,200	692,900	720,800
Employed in academe	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
Employed in business	169,500	175,300	190,100	216,100	227,400	223,700	232,500	253,200	265,600	276,500
Employed in government	46,600	48,000	53,500	52,100	54,600	57,100	56,700	62,600	66,100	66,000
Employed in nonprofits	23,600	23,800	26,300	27,500	28,400	29,600	38,600	42,900	45,100	45,500
Employed in K-12 education and other sectors	66,500	10,900	10,900	12,700	12,600	14,200	13,300	11,500	13,400	14,400

S&E science and engineering

Notes: Employed includes full time and part time employment. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15). Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, US military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 education and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/school system (A15)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

female.[3] So while female representation in the SEH doctorate population certainly increased between 1993 and 2013, the representation of women among SEH doctorates still lags behind their percentage in the adult population as a whole.

The proportion of females in SEH occupations increased by 9 percentage points in the business sector from 1993 to 2013, 13 percentage points in the nonprofit sector, 15 percentage points in academe and K-12 education, and 17 percentage points in government (Table 5.2). These double-digit percentage point increases nearly across the board demonstrate great strides in addressing female underrepresentation in SEH occupations. The percentage of postdoctoral scholars ("postdocs") who were female also steadily increased during this time period, rising from 30 % in 1993 to 42 % in 2013. Particularly large gains in the percentage of female postdocs were observed in the sectors of business (22 percentage points) and academe (13.5 percentage points) (Appendix Table 5.7).

Similar trends were observed for most fields of degree, where from 1993 to 2013, the representation of females showed steady increases over time. With the notable exception of the computer/information sciences field, where female representation from 1993 to 2013 increased only from 15 to 18 %, all other fields showed increases ranging from 9 percentage points (engineering) to 16 percentage points (health and psychology) during this same time period. When we observed economic sector and field of doctorate together, we found that females demonstrated particularly pronounced gains from 1993 to 2013, including a 14 percentage point increase in the biological/agricultural/environmental life sciences field in academe and a 21 percentage point increase in the health field in business (SESTAT Data Tool 2016).

5.3.4 US Citizenship

The topic of citizenship is of particular interest as it relates to the science and engineering workforce in the US Given the global mobility of today's highly-skilled workers, the NSF has instituted an international version of the SDR to obtain information on the career paths of citizens and non-citizens alike. The international survey is for those individuals who receive an SEH doctoral degree in the US, but leave the US afterward. The percentage of SEH doctorate holders employed in the US who were US citizens decreased from 1993 (92 %) to 2013 (86 %). Compared to 1993, the percentage of employed SEH doctorate holders who were U.S. citizens was slightly lower in 2013 across all economic sectors, except the K-12 education sector (Table 5.3).

Similar trends were observed for postdoc positions, where the percentage of postdocs who were US citizens was about the same in 1993 (69 %) as in 2003 (67 %), but dropped noticeably in 2013 (59 %). This downward trend in the percentage of postdoc positions held by US citizens was mirrored across the various economic sectors, except for the K-12 education sector, where small sample sizes precluded comparisons (SESTAT Data Tool 2016).

[3] We have chosen the 25–75 age group because the US Census Bureau uses the adult population 25 and older as its standard in measuring educational attainment. See Table 2 in (US Census Bureau 2013).

Table 5.2 Employed S&E doctorate-holders by employment sector and sex: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All employed	462,900	484,800	518,400	553,400	574,900	593,300	621,600	651,200	692,900	720,800
Male	369,300	379,500	399,100	419,900	427,800	432,200	438,900	451,200	472,700	480,800
Female	93,600	105,300	119,300	133,500	147,100	161,200	182,700	199,900	220,200	240,000
Employed in academe	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
Males	170,400	173,400	177,700	179,700	180,200	188,300	188,900	185,500	195,600	201,700
Females	46,300	53,400	59,800	65,200	71,600	80,400	91,800	95,400	107,100	116,700
Employed in business	169,500	175,300	190,100	216,100	227,400	223,700	232,500	253,200	265,600	276,500
Males	140,600	144,300	155,900	174,500	180,500	174,600	179,200	192,300	200,300	203,700
Females	28,900	31,000	34,300	41,600	46,800	49,100	53,400	60,900	65,300	72,900
Employed in government	46,600	48,000	53,500	52,100	54,600	57,100	56,700	62,600	66,100	66,000
Males	37,300	37,900	41,700	40,200	41,900	42,500	40,000	42,400	43,500	41,800
Females	96,300	10,000	11,800	11,900	12,800	14,600	16,700	20,200	22,500	24,300
Employed in nonprofits	23,600	23,800	26,300	27,500	28,400	29,600	38,600	42,900	45,100	45,500
Males	16,900	17,000	17,600	18,000	18,100	18,800	23,900	25,500	26,700	26,800
Females	66,700	66,900	86,700	96,600	10,300	10,800	14,700	17,400	18,400	18,700
Employed in K-12 and other sectors	66,500	10,900	10,900	12,700	12,600	14,200	13,300	11,500	13,400	14,400
Males	46,100	66,900	66,200	76,500	76,100	86,000	76,100	56,500	66,500	66,900
Females	26,400	46,000	46,700	56,200	56,600	66,200	66,200	66,000	66,900	76,500

S&E science and engineering

Notes: Employed includes full time and part time employment. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15). Business/Industry includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, US military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/school system (A15)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.3 Employed S&E doctorate-holders by employment sector and citizenship, according to broad field of degree: 1993, 2003, 2013

		Sciences								
	All employed	All sciences	Biological/ agricultural/ environmental life sciences	Computer/ information sciences	Mathematics/ statistics	Physical sciences	Psychology	Social sciences	Engineering	Health
1993 employed, all sectors	462,900	374,100	110,900	56,200	22,800	98,500	71,000	65,700	75,100	13,700
US citizen	425,100	349,300	104,400	36,800	20,200	90,600	69,700	60,500	62,800	12,900
Permanent resident	28,500	18,300	46,500	1000	16,900	56,500	16,200	46,200	96,700	600
Temporary visa	96,300	66,500	26,000	300	700	26,400	100	900	26,600	200
Employed in academe	216,700	184,300	61,400	26,500	15,300	38,100	24,500	42,500	25,000	76,400
US citizen	197,000	169,400	57,300	16,700	13,300	34,300	23,800	38,900	20,500	76,000
Permanent resident	14,400	10,700	26,700	600	16,500	26,200	600	36,100	36,400	300
Temporary visa	56,300	46,200	16,500	100	500	16,500	100	500	1000	100
Employed in business	169,500	123,500	29,800	26,400	56,600	46,300	29,100	10,400	42,300	36,600
US citizen	154,800	116,500	28,300	16,900	56,100	42,900	28,600	96,700	35,000	36,300
Permanent resident	11,800	56,700	16,200	400	400	26,800	400	600	56,900	200
Temporary visa	26,800	16,400	300	200	100	700	D	100	16,400	100
Employed in government	46,600	39,700	13,400	100	16,100	96,500	86,200	76,400	56,400	16,500
US citizen	45,400	38,800	13,000	100	16,100	96,300	86,000	76,300	56,100	16,500
Permanent resident	900	700	300	D	D	100	200	100	200	[a]
Temporary visa	300	200	100	D	D	100	D	D	100	D
Employed in nonprofits	23,600	20,300	56,400	100	600	46,100	66,600	36,600	26,300	16,000

(continued)

Table 5.3 (continued)

		Sciences								
	All employed	All sciences	Biological/ agricultural/ environmental life sciences	Computer/ information sciences	Mathematics/ statistics	Physical sciences	Psychology	Social sciences	Engineering	Health
US citizen	22,200	19,200	5,000	100	600	3,600	6,500	3,400	2,000	1,000
Permanent resident	1,000	900	300	D	D	400	D	200	200	[a]
Temporary visa	400	300	100	D	D	100	D	D	100	D
Employed in K-12 education and other sectors	6,500	6,200	800	D	200	600	2,800	1,800	100	200
US citizen	5,700	5400	700	D	100	500	2,700	1,300	100	100
Permanent resident	400	300	100	D	D	D	D	200	D	D
Temporary visa	500	400	D	D	D	D	D	300	D	D
2003 employed, all sectors	593,300	468,600	145,800	12,000	28,300	112,700	91,400	78,400	101,500	23,200
US citizen	534,000	429,700	132,900	9,000	24,400	101,800	89,600	72,000	82,900	21,300
Permanent resident	39,600	26,000	8,600	2,100	2,500	7,000	1,400	4,400	12,400	1,200
Temporary visa	19,700	12,800	4,200	800	1,400	3,900	500	2100	6,200	600
Employed in academe	268,700	226,600	78,900	5,400	17,200	41,600	33,100	50,500	28,600	13,500
US citizen	242,200	205,500	71,100	4,100	14,800	37,200	32,100	46,100	24,400	12,300
Permanent resident	16,900	13,500	4,800	900	1,600	2,400	700	3,100	2,500	800
Temporary visa	9,700	7,600	3,000	400	800	1,900	300	1,200	1,700	400
Employed in business	223,700	157,700	41,700	5,800	8,400	53,000	36,000	12,800	60,400	5,700
US citizen	196,300	144,300	38,200	4,300	7,100	47,400	35,400	12,000	46,900	5,100

Permanent resident	19,600	10,000	2800	1100	800	4,100	500	700	9,200	300
Temporary visa	7,800	3,400	700	400	500	1,500	D	200	4,200	200
Employed in government	57,100	46,500	15,800	400	1,800	11,800	8,600	8,200	8,500	2,000
US citizen	55,000	45,000	15,100	400	1,700	11,400	8,500	7,800	8,100	2,000
Permanent resident	1,300	1,000	500	D	D	200	D	300	300	D
Temporary visa	700	600	200	D	D	300	D	D	D	D
Employed in nonprofits	29,600	25,200	7,200	300	800	4,000	8,500	4,400	2,900	1,600
US citizen	27,700	23,600	6,600	200	700	3,600	8,500	4,100	2,600	1,500
Permanent resident	1,200	1,000	400	D	D	300	D	200	200	D
Temporary visa	700	600	300	D	D	100	D	100	D	D
Employed in K-12 education and other sectors	14,200	12,500	2,100	D	200	2,300	5,200	2,700	1100	500
US citizen	12,800	11,400	1,900	D	100	2,200	5,100	2,000	1,000	500
Permanent resident	600	600	200	D	D	S	D	200	D	D
Temporary visa	700	600	D	D	D	D	D	500	D	D
2013 employed, all sectors	720,800	553,600	183,500	21,900	32,600	122,200	104,900	88,500	133,700	33,500
US citizen	622,900	491,400	163,700	15,800	25,500	105,600	102,200	78,700	100,800	30,800
Permanent resident	70,100	45,300	14,000	4,500	5,200	12,100	2,100	7,400	22,900	1,800
Temporary visa	27,800	16,900	5,800	1,600	1,900	4,500	600	2,400	10,000	900
Employed in academe	318,300	263,000	92,700	8,500	19,600	46,700	37,500	58,000	35,800	19,500
US citizen	274,300	229,300	81,300	6,400	15,700	38,900	36,100	50,900	27,200	17,900

(continued)

Table 5.3 (continued)

		Sciences								
	All employed	All sciences	Biological/ agricultural/ environmental life sciences	Computer/ information sciences	Mathematics/ statistics	Physical sciences	Psychology	Social sciences	Engineering	Health
Permanent resident	31,000	24,500	7,700	1,700	3,000	5,300	1,000	5,700	5,500	1,000
Temporary visa	13,000	9,300	3,700	400	1,000	2,500	300	1,400	3,200	600
Employed in business	276,500	187,200	54,000	11,400	9,800	55,200	41,300	15,500	82,200	7,100
US citizen	233,100	166,400	48,900	7,700	7,000	48,100	40,500	14,100	60,200	6,400
Permanent resident	32,600	16,200	4,200	2,600	2,000	5,700	700	1,100	15,800	600
Temporary visa	10,900	4,600	900	1,100	800	1,400	D	300	6,100	200
Employed in government	66,000	52,800	19,700	900	1,500	11,900	11,600	7,300	10,100	3,100
US citizen	62,100	50,200	18,600	700	1,400	11,000	11,500	7,000	8,900	2,900
Permanent resident	2,800	1,900	800	D	D	500	D	300	800	D
Temporary visa	1,200	800	300	100	D	400	D	D	300	D
Employed in nonprofits	45,500	37,700	14,000	900	1,300	6,300	10,000	5,300	4,600	3,200
US citizen	40,500	33,900	11,900	700	1,000	5,600	9,700	4,900	3,500	3,000
Permanent resident	3,100	2,300	1,200	D	D	400	200	300	600	200
Temporary visa	1,900	1,500	900	D	D	200	D	200	400	D
Employed in K-12 education and other sectors	14,400	12,800	3,100	200	400	2,100	4,500	2,400	1,100	500
US citizen	13,000	11,600	2,900	S	300	2,000	4,400	1,800	900	500

Permanent resident	600	500	100	D	D	D	D	S	D	D
Temporary visa	800	700	D	D	D	D	D	500	D	D

S&E science and engineering
D suppressed to avoid disclosure of confidential information
S suppressed for reliability; coefficient of variation exceeds 50 %
[a]Suppressed when population estimate <50
Notes: Employed includes full time and part time employment. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15). Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, US military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 education and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/school system (A15)
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993, 2003, 2013

Between 1993 and 2013, the change in the percentage of SEH doctorate holders who were US citizens depended on the field of degree, such that there was no change for computer/information sciences and psychology, but an 8–10 percentage point decline for engineering and mathematics/statistics, respectively (Table 5.3).

The percentage of SEH doctorate holders who were US citizens varied by field of degree within economic sector. Between 1993 and 2013, the percentage of SEH doctorate holders employed in academe who were US citizens remained constant or decreased for all fields, including computer/information sciences, whose observed difference was not statistically significant. The percentage of US citizens among SEH doctorate holders in the field of computer/information sciences who were employed in business decreased by nearly 10 percentage points during the same time period (Table 5.3).

5.3.5 Employment Among Early Career Doctorate Holders

The study of early career doctorate holders and post-doctoral appointments provides insight into the development of the career choices and continuing development of the SEH doctoral workforce. For this analysis, early career doctorate holders are defined as individuals who had obtained their doctorates within the most recent 5 years. Between 1993 and 2003, the percentage of early career doctorate holders who held postdoc positions declined by approximately 5 percentage points (to 15 % in 2003), but rebounded in 2013 (19 %) to be comparable to the percentage observed for 1993 (20 %). Similar patterns were observed within the various economic sectors, with the exception of K-12 education, where insufficient sample sizes did not allow for comparisons over time. Notably, for nonprofits, the increase between 2003 and 2013 was particularly large (19 percentage points).

The nonprofit sector was the only sector that showed a higher percentage of postdoc positions in its workforce in 2013 than in 1993 (Appendix Table 5.8). The proliferation of postdoc positions within the nonprofit sector may be due to the relatively lower costs of postdoc positions, which may not have as many benefits or overhead costs as other positions. Within the academic sector, which represented the largest proportion of postdoc positions and was the only sector that had sufficient sample sizes to allow for cross-field comparisons, we were able to detect slight shifts in the distribution of postdoc positions by fields of degree. These included the physical sciences and biological/agricultural/environmental life sciences fields, where the combined percentage of early career doctorates that held postdocs declined from 53 % to 49 % from 1993 to 2013. By way of contrast, the percentage of academic sector early career doctorates holding postdoc positions in engineering increased from 20 % of the total to 26 % of early career doctorate holders in the same time period (SESTAT Data Tool 2016).

Recent doctorates were more likely to report R&D as a primary or secondary work activity than were doctorates who were not recent graduates. In 2013, 74 % of SEH doctorates who had obtained doctoral degrees within the most recent 5 years reported that R&D was their primary or secondary work activity, compared to 60 % of SEH doctorates who had attained their degree within the past 11–15 years and

54 % of SEH doctorates who had attained their doctoral degree more than 25 years earlier. A similar pattern is apparent in various fields of study (SESTAT Data Tool 2016) as well as for the different economic sectors, with the exception of the K-12 education sector, where the percentage of doctorates reporting R&D activity was roughly comparable across the different groupings of years since doctorate attainment (SESTAT Data Tool 2016). This phenomenon is well-documented in research on the SEH workforce, as the *2014 Science and Engineering Indicators* describes: "The decline in R&D activity over the course of individuals' careers may reflect movement into management, growth of other career interests, or possession of scientific knowledge and skills that are no longer in demand. It may also reflect increased opportunity for more experienced scientists to perform functions involving the interpretation and use of, as opposed to the creation and development of, scientific knowledge." (National Science Foundation 2014, Chap. 3, s2).

Not surprisingly, years since attainment of doctorate also factored in salary, with more recent doctorates reporting lower salary than mid-career or more experienced doctorate holders. In 2013, full-time employed doctorate holders who had received doctorates in the most recent 5 years had a median annual salary of $73,000 compared to a median annual salary of $102,000 reported by full-time employed doctorate holders who received their degrees within the previous 11–15 years, and a median annual salary of $128,000 reported by full-time employed doctorate holders who received their doctorates more than 25 years previously (National Science Foundation 2013). This pattern held in all economic sectors, except for those in the K-12 education sector. In that sector, the key career milestone appears to be 6–10 years, when median annual salary for full-time employed SEH doctorates takes a significant step upward, but does not continue increasing after that point. Nevertheless, the earnings of early career doctorates are still substantially higher than that of the general population, whose median annual full-time salary is around $35,000.[4]

5.4 Trends in Academic Employment from 1993 to 2013

As noted earlier, academe is the largest employer of SEH doctorate holders. Although the percentages varied over time, the most common position within academe was full-time senior faculty, followed by full-time junior faculty. Between 1993 and 2013, the percentage of full-time senior faculty decreased by 9 percentage points to 47 % of the total workforce in academe, whereas the percentage of other full-time academic positions (including administrative and staff positions, as well as adjunct faculty and instructors) increased by 7 percentage points to 19 %. Other types of academic positions, such as full-time junior faculty, postdocs, and part-time positions, were represented in much the same proportions in the academic workforce throughout this period (Table 5.4). As a percentage of the workforce at 4-year colleges and universities, health science doctorates showed no change in

[4] Derived by multiplying the median hourly wage for all workers by 2080 h. This compares to a national mean annual salary of $46,440, according to US Bureau of Labor Statistics (2013).

Table 5.4 S&E doctorate-holders employed in academe, by rank/position: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Employed in academe, all ranks or positions	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
Full time senior faculty[a]	122,200	127,800	132,200	136,700	137,000	130,000	131,400	136,600	145,700	150,300
Full time junior faculty[b]	38,900	41,100	42,700	43,600	46,100	48,300	54,300	51,700	55,200	57,400
Other full time positions[c]	25,900	32,000	30,300	33,100	36,100	51,500	48,000	50,600	53,800	61,300
Postdocs[d]	19,400	17,000	18,100	17,900	17,000	15,900	22,700	17,900	22,400	21,000
Part time positions[e]	10,400	8,900	14,300	13,600	15,700	23,000	24,200	24,000	25,600	28,400

S&E science and engineering

[a]For 1993–2001 SDR data: Full time senior faculty includes full time employed in academe whose faculty rank was professor or associate professor; excludes respondents whose principal job was postdoc. For 2003–2013 SDR data: Full time senior faculty includes full time employed in academe whose type of academic position was teaching faculty or research faculty (A16) and whose faculty rank was professor or associate professor (A17)

[b]For 1993–2001 SDR data: Full time junior faculty includes full time employed in academe whose faculty rank was assistant professor; excludes respondents whose principal job was postdoc. For 2003–2013 SDR data: Full time junior faculty includes full time employed in academe whose type of academic position was teaching faculty or research faculty (A16) and whose faculty rank was assistant professor (A17)

[c]For 1993–2001 SDR data: Other full time positions include those full time employed in academe whose faculty rank is instructor, lecturer, adjunct faculty, other-specify, or not applicable (at institution or for position); excludes respondents whose principal job is postdoc. For 2003–2013 SDR data: Other full time positions include those full time employed in academe whose type of academic position was president/provost/chancellor, dean, adjunct faculty, research assistant, teaching assistant, or other position (A16); also includes those full time employed in academe who responded research faculty or teaching faculty (A16) and responded instructor, lecturer, other-specify, or not applicable (A17)

[d]For 1993–2001 SDR data: Postdocs include those full time employed in academe whose principal job is postdoc (regardless of faculty rank); part time postdocs are not counted here. For 2003–2013 SDR data: Postdocs include those full time employed in academe whose type of academic position was postdoc (A16); part time postdocs are not counted here

[e]Part time positions include those part time employed in academe regardless of response to position (A16) or rank (A17); part time postdocs are counted here. Part time employment does not exclude those who are part time because they are retired or students (in Chap. 5 of S&E Indicators, these categories of part timers are excluded)

Notes: Full time employed is working 35 hours or more per week; part time employed is less than 35 hours per week. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

their overall employment; however, their employment decreased 6 percentage points at medical schools/research institutes (Appendix Table 5.9).

Teaching and research were the primary work activities SEH doctorate holders in academe reported. While teaching remained the most prevalent primary work activity cited, fewer than half of SEH doctorate holders (46 %) reported it as such in 2013. This contrasted to 52 % of doctorate holders in academe reporting teaching as their primary work activity in 1993. In the same period, the proportion of SEH doctorate holders citing research as their primary work activity increased from about 34 to 39 % between 1993 and 2013. The finding that teaching declined over time appeared to be driven mostly by declines in teaching reported by faculty within very high research institutions. Faculty in other types of institutions, such as doctoral research institutions or comprehensive institutions, reported steady levels of teaching across years (Appendix Table 5.10).

5.4.1 Gender Differences in Academic Employment

Mirroring the trends observed with SEH employment in the field more generally, females markedly increased their representation in academe, rising from 21 % of the academic workforce in 1993 to 30 % in 2003 to 37 % in 2013. Between 1993 and 2013, females showed steady increases across different ranks and positions in academe, ranging from a 7-percentage point increase in part-time positions to a 15-percentage point increase in full-time senior faculty positions. Although females showed demonstrable gains in representation, they continued to be underrepresented at all positions in academe in 2013, except for part-time positions, where males and females were equally represented. Females continued to lag behind males in full-time senior faculty positions (29 % versus 71 %), full-time junior faculty positions (45 % versus 55 %), and full-time postdoc positions (40 % versus 60 %) (Appendix Table 5.11).

5.4.2 Early Career and Recent Doctorates Employed in Academe

Early career employment in academe takes three main forms: tenured or tenure-track appointments, postdocs, and non-tenure track appointments. The two decades under consideration illustrated a broader trend in US academia, a move away from tenure and tenure-track employment (see, for example, Kezar and Maxey 2013). Between 1993 and 2003, the percentage of early career doctorates who reported being tenured or on a tenure track remained steady, but decreased nearly 10 percentage points between 2003 and 2013. Similar patterns were observed for virtually every field of degree, with the exceptions of computer/information sciences and psychology, where the percentage of tenured or tenure-track positions remained steady between 2003 and 2013. However, the computer/information sciences field experienced a 17 percentage point decline in tenure-track positions during the previous decade (i.e., between 1993 and 2003), and the psychology field showed small, but incremental declines over the years, resulting in a nearly 6 percentage point drop between 1993 and 2013. Thus, all fields experienced a decline in the percentage of tenured or tenure-track positions within the past two decades (Appendix Table 5.12).

The decline from 1993 to 2013 in tenure-track employment reflects mainly an increase in non-tenure track appointments since the percentages holding postdocs were stable. Across all fields, the percentage not in a tenure track position or postdoc increased from 25 % in 1993 to 35 % in 2013. This pattern held within most fields as well, with the partial exception of engineering, where the percentage of early career doctorate recipients with postdocs did increase from 19 % in 1993 to 30 % in 2013 while the percentage not in a tenure track or postdoc also increased from 24 % in 1993 to 31 % in 2013 (Appendix Table 5.12).

5.5 SEH Doctorates in Business

5.5.1 Employment in S&E Occupations within Business

Scientists and engineers play an important role in business. Second only to academe as an employer of SEH doctorate holders, business employed 276,500 SEH doctorate holders in 2013. Based on occupation characteristics, a doctorate recipient's principal job is classified as a science and engineering (S&E) occupation, a science and engineering-related occupation, or an occupation unrelated to science and engineering.[5] In 2013, two-thirds (66 %) of the doctorate holders employed in business worked in science and engineering (S&E) occupations, while 10 % worked in S&E-related, and 24 % worked in non-S&E-related occupations. These percentages were unchanged from 2003[6] (Table 5.5).

In 2013, 79 % of early career doctorates employed in the business sector worked in S&E occupations and 15 % worked in non-S&E occupations, while 59 % who had held their doctorate for more than 25 years worked in S&E occupations and 32 % worked in non-S&E occupations. Similar distributions were found in 1993 and 2003. At all three time points (1993, 2003, and 2013), the proportion of doctorate holders working in S&E occupations decreased substantially as years from doctorate receipt increased (Table 5.5).

The proportions employed in S&E occupations within the business sector also differed according to the doctorate recipients' fields of study. In 2013, large proportions of doctorate holders in the fields of computer/information sciences (80 %), mathematics/statistics (72 %), physical sciences (68 %), psychology (75 %), and engineering (74 %) were employed in S&E occupations (SESTAT Data Tool 2016).

The pattern of greater proportions of more recent doctorate recipients, rather than older cohort members, being employed in S&E occupations within the business sector

[5] S&E occupations include: computer and mathematical scientists; biological, agricultural and other life scientists; physical and related scientists; social and related scientists including psychologists; engineers. These also include postsecondary teachers in all of these fields. S&E-related occupations include health-related occupations, S&E managers, S&E pre-college teachers, S&E technicians and technologists. Non-S&E occupations encompass all others, including college teachers of non-S&E fields, non S&E managers, editors, sales, social services and other fields unrelated to science and engineering.

[6] Comparisons with years prior to 2003 should not be made given the 2003 move of "Health-related occupations" from "S&E occupations" to "S&E-related occupations."

Table 5.5 S&E doctorate-holders employed in business by broad occupation, according to years since doctorate: 1993, 2003, 2013

	Years since doctorate					
	<=5	6–10	11–15	16–20	21–25	>25
1993, all occupations	30,700	29,900	30,000	29,400	26,000	23,500
S&E occupations	25,400	21,500	18,400	15,100	12,900	12,600
S&E-related occupations	1,300	1,500	1,800	2,000	1,800	1,100
Non-S&E occupations	4,100	6,900	9,800	12,200	11,400	9,700
2003, all occupations	38,100	44,800	35,000	28,300	27,200	50,400
S&E occupations	30,700	32,400	23,300	18,400	16,100	29,600
S&E-related occupations	2,500	4,700	3,800	3,600	3,800	5,800
Non-S&E occupations	5,000	7,600	7,800	6,300	7,300	15,000
2013, all occupations	37,400	42,300	41,400	42,500	33,200	79,800
S&E occupations	29,400	32,200	26,900	25,900	20,500	47,400
S&E-related occupations	2,300	3,400	5,000	5,300	3,800	7,100
Non-S&E occupations	5,700	6,700	9,600	11,200	8,900	25,300

S&E science and engineering
Notes: Employed includes full time and part time employment. Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Years since doctorate is based on academic year. Comparisons should not be made between 1993 and the subsequent years given the 2003 move of "Health-related occupations" from "S&E occupations" to "S&E-related occupations." This is plausibly the main explanation for the increase in S&E-related occupations starting in 2003
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993, 2003, 2013

is also found within most of the doctorate recipients' fields of doctoral study. Newer cohort doctorate holders from all fields of study were more likely to be employed in S&E occupations than were the oldest cohort members, with the exception of psychology, where the proportion of oldest cohort members in S&E occupations was larger than the proportion for the newest cohort (SESTAT Data Tool 2016).

5.5.2 Relation of Occupation to Field of Doctoral Study in the Business Sector

Overall, about two-thirds of employed SEH doctorate holders reported that their occupation was closely related to their field of doctoral study. However, in the business sector, this relationship is weaker than in other sectors. In 2013, more than half (52 %) of doctorate holders employed in the business sector reported that their principal job was closely related to the field of their degree, while 34 % viewed their job as being somewhat related, and 13 % saw it as not at all related. The proportions were almost identical to these in 2003 and 1993 (SESTAT Data Tool 2016).

Higher proportions reported their occupations were closely related to their field of study among those who were within 5 years of earning their doctorates compared to those who were further removed in time from earning the doctorate. In 2013, 61 % of employed doctorate holders who had held a doctorate for 5 or fewer years reported that their job was closely related to the field of their degree, but among those who had held a doctorate for 25 or more years only 48 % reported their job was closely related. The pattern was similar in 2003 and 1993 (SESTAT Data Tool 2016).

This pattern of more recent graduates reporting jobs more closely related to degree field than more senior scientists and engineers was also found within some fields of doctoral study. No differences between the most junior and most senior cohorts were found for computer/information sciences, psychology, and health doctorate holders. In contrast, the percentages reporting their jobs and degrees were closely related were significantly lower in the most senior compared to the most junior cohorts among those earning doctorates in biological/agricultural/environmental life sciences, mathematics/statistics, physical sciences, social sciences, and engineering (SESTAT Data Tool 2016).

Some doctoral scientists and engineers work in jobs completely unrelated to their degrees. Among the relatively small number of doctorate holders employed by businesses who reported their job is unrelated to the field of their doctorate, self-reported reasons for working out of their doctoral field varied. Over the period 1993–2013, the proportion of doctorate holders working in a job unrelated to their field of degree who reported they were unable to find a job in their field declined by half, while the proportion that reported a change in career interests increased by a third. In all years except 1997, the largest share of doctorate holders working outside their field reported reasons other than unavailability of a job or a change in career interests (SESTAT Data Tool 2016).

5.5.3 Self-Employment

Self-employment among doctoral scientists and engineers grew considerably over the two decades. In 2013, 31 % of the 276,500 doctorate holders working in business were self-employed business owners. The percentage of self-employed changed little from 2003 to 2013 but was 24 % in 1993 (Appendix Table 5.13).

Doctorate holders in science and health fields on average were more likely to be self-employed business owners than were doctorate recipients in engineering fields in 2013. The percentages of doctorate holders working in business who were self-employed in 2013 ranged from 75 % in psychology, 47 % in social sciences, and 43 % in health, to 28 % in biological/agricultural/environmental life sciences and less than 20 % in physical sciences, engineering, computer/information sciences, and mathematics/statistics. The overall increase in the self-employment rate between 1993 and 2013 of about 7 percentage points was also found within most fields of doctoral study. Two exceptions were mathematics/statistics, which had no significant increase, and health, whose rate of self-employment increased substantially from 30 % in 1993 to 43 % in 2013 (Appendix Table 5.13).

Self-employment rates among those in business were higher among those with more years since earning their doctorates. In 2013, 15 % of those 5 or less years since doctorate award were self-employed compared to 51 % of those with more than 25 years since earning their doctorate. This pattern was evident in all fields of doctoral study, and held for 2003 and 1993 as well as 2013 (SESTAT Data Tool 2016).

5.5.4 Business Size

Doctoral scientists and engineers in the business sector are more likely to work at the US's largest corporations than are members of the US workforce in general. The business firms employing doctorate holders vary in their total numbers of employees. In 2013, 41 % of the doctorate holders in business worked in firms with fewer than 100 employees, 12 % in firms with 100–999 employees, 48 % in firms employing 1,000 or more (Appendix Table 5.14). The comparable figures for the employed US workforce were 47 %, 17 % and 36 %, respectively, according the March 2013 Current Population Survey.[7]

Over the period 1995 to 2013, the proportions of doctorate holders working in businesses of these size categories were relatively stable, both overall and within the field of study groupings. Where measurements are comparable across years, almost no year-to-year difference was greater than a few percentage points in science, engineering or health fields (Appendix Table 5.14). Early career doctorates working in business were more likely than older cohort members to work in firms employing 1,000 or more workers. In 2013, 61 % of the newest cohort and 27 % of those more than 25 years since the doctorate worked in such firms. This pattern in which recent graduates were more likely to work for large firms than were the most senior scientists held within each of the field of study groupings where sufficient sample size afforded a comparison (SESTAT Data Tool 2016).

5.6 Employment as Researchers

A strong R&D program helps companies to stay competitive within the global economy, which may explain why about 60 % of the doctorate holders working in the business sector in 2013 identified their primary or secondary work activities as basic research, applied research, development, or design (R&D). Within the field of study grouping, the percentages of doctorate holders employed in business working in R&D in 2013 ranged from 74 % in engineering to 69 % in computer/information sciences and physical sciences, 65 % in mathematics/statistics, 59 % in life sciences, 55 % in health, 47 % in social sciences, and 20 % in psychology (Appendix Table 5.15).

Doctorate holders employed by small firms (less than 100 employees) were less likely to work in R&D than their counterparts employed by larger firms. In 2013, 44 % of those in small firms worked in R&D compared to 70 % of those in firms employing 25,000 or more. This pattern was found within each of the field of study groupings except social sciences, computer/information sciences, and mathematics/statistics where the proportions working in R&D in the largest and smallest firms were about the same. The differences in R&D rates between the smallest and largest firms were particularly large in psychology and health (Appendix Table 5.15).

[7] The Current Population Survey is a monthly household survey conducted by the US Census Bureau and the US Bureau of Labor Statistics. The figures reported here were calculated from the online IPUMS-CPS tool available at the Minnesota Population Center at www.IPUMS.org.

5.7 Conclusion

Over the past two decades, growth in the stock of US-trained SEH doctorate-holding scientists and engineers has been accompanied by their consistently high levels of labor force participation and employment. This combination of growth in the US production and employment of US-trained SEH doctorates is indicative of the country's continued need for research and development expertise. Perhaps the most striking growth over the past two decades has been the increased representation of women in the doctoral SEH workforce across all sectors and from all fields of study. Despite these significant gains, women remain underrepresented in engineering, computer/information sciences, and physical sciences.

The additional growth in the number of non-US citizens who are US-trained SEH doctorate holders is indicative of the global impact of the US higher education system. Research indicates that the "stay rate" of non-US citizens after earning their doctorate has remained high over the 20-year span.[8] Growth is also seen in doctoral SEH education programs outside the US as the demand for doctoral expertise in other national economies increases.[9]

In the academic sector, where most SEH doctorate holders work, the last two decades have witnessed significant changes to the work environment. Specifically, our research has noted a decline in the percentage of full-time faculty positions, and an increase in full-time administrative and staff positions. Meanwhile, the availability of tenure-track positions leading to tenured employment has decreased, especially for early career doctorate holders.

A large share of the US doctoral SEH labor force—38 %—is employed by private businesses with about three-quarters working in S&E or S&E-related occupations. Their careers are typically focused on research and development, particularly for the most recent doctorate recipients. Moreover, almost a third of those employed in business are self-employed. A correspondingly high percentage (over 85 %) reported their jobs to be closely or at least somewhat related to their field of doctoral study. These data generally indicate a diverse labor market for SEH doctorate holders in the US, with significant opportunities to pursue nonacademic careers and define new applications and business opportunities for their areas of expertise.

Appendix

[8] See the research on "stay-rates" of non-US born, US-trained doctorates in (NSF 2014, Chap. 3) at http://www.nsf.gov/statistics/seind14/index.cfm/chapter-3/c3s6.htm.

[9] Higher education experts have acknowledged this challenge to the US's leading role in doctoral education. See: Council of Graduate Schools and Educational Testing Service (2010).

Table 5.6 Employed S&E doctorate-holders by employment sector and researcher status: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All employed, all sectors	462,900	484,800	518,400	553,400	574,900	593,300	621,600	651,200	692,900	720,800
% reporting R&D as primary/ secondary work activity	64.6	64.4	64.4	63.7	63.8	62.7	62.2	62.8	62.1	61.3
Employed in academe	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
% reporting R&D as primary/ secondary work activity	70.3	70.6	70.3	69.4	69.6	68.1	66.5	66.9	66.4	64.5
Employed in business	169,500	175,300	190,100	216,100	227,400	223,700	232,500	253,200	265,600	276,500
% reporting R&D as primary/ secondary work activity	61.0	60.4	60.8	60.4	60.9	59.3	59.4	60.9	59.8	59.7
Employed in government	46,600	48,000	53,500	52,100	54,600	57,100	56,700	62,600	66,100	66,000
% reporting R&D as primary/ secondary work activity	62.0	61.1	64.1	65.3	64.2	64.5	63.4	62.7	62.5	62.1
Employed in nonprofits	23,600	23,800	26,300	27,500	28,400	29,600	38,600	42,900	45,100	45,500
% reporting R&D as primary/ secondary work activity	56.2	54.7	50.8	49.8	50.7	52.6	57.3	58.3	56.9	57.8
Employed in K-12 education and other sectors	6,500	10,900	10,900	12,700	12,600	14,200	13,300	11,500	13,400	14,400
% reporting R&D as primary/ secondary work activity	21.6	34.6	32.7	32.3	28.0	26.4	28.9	23.4	25.5	26.2

S&E science and engineering

Notes: Employed includes full time and part time employment. Researchers are doctorate-holders reporting primary or secondary work activity as basic research, applied research, development, or design (A30, A31). Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/ school system (A15). Business/Industry includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, U.S. military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 education and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/ school system (A15)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.7 Employed early career S&E postdocs by employment sector and sex: 1993, 2003, 2013

	1993	2003	2013
Early career postdocs, all economic sectors	19,100	16,800	22,600
Female postdocs	5,700	6,800	9,400
Percent	29.6	40.4	41.7
Early career postdocs in academe	14,700	13,700	16,900
Female postdocs	4,300	5,300	7,200
Percent	29.1	38.7	42.6
Early career postdocs in business	1,200	500	600
Female postdocs	400	300	300
Percent	33.8	50.6	56.2
Early career postdocs in government	1,900	1,700	2,400
Female postdocs	500	700	800
Percent	28.3	41.8	34.5
Early career postdocs in nonprofits	1,400	700	2,400
Female postdocs	500	400	900
Percent	34.5	59.6	37.8
Early career postdocs in K-12 education and other sectors	S	200	100
Female postdocs	D	100	100
Percent	D	52.5	62.7

S&E science and engineering
D suppressed to avoid disclosure of confidential information
S suppressed for reliability; coefficient of variation exceeds 50 %
Notes: Employed includes full time and part time employment. Early career is 5 years or less since doctorate, where years since doctorate is based on academic year. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15). Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, U.S. military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 education and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/school system (A15)
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993, 2003, 2013

Table 5.8 Early career S&E doctorate-holders by employment sector and postdoc status: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Early career doctorate-holders, all economic sectors	94,300	100,200	110,100	115,800	116,800	115,600	113,600	124,800	136,400	117,400
Postdoctoral appointment	19,100	19,400	21,700	20,800	18,900	16,800	26,700	23,500	26,800	22,600
Percent	20.3	19.3	19.7	18.0	16.2	14.6	23.5	18.8	19.7	19.2
Early career doctorate-holders in academe	47,000	50,400	54,000	52,400	52,800	58,900	62,800	61,900	68,400	58,700
Postdoctoral appointment	14,700	14,900	16,300	16,200	15,300	13,700	21,000	16,100	20,400	16,900
Percent	31.2	29.5	30.3	30.9	28.9	23.3	33.4	26.0	29.8	28.9
Early career doctorate-holders in business	30,700	32,400	37,300	44,700	45,000	38,100	31,000	40,300	44,100	37,400
Postdoctoral appointment	1,200	1,100	1,100	900	900	500	1,100	1,300	1,000	600
Percent	3.8	3.4	3.0	2.0	1.9	1.3	3.4	3.1	2.3	1.7
Early career doctorate-holders in government	8,900	8,900	10,000	9,900	10,100	9,900	9,900	11,500	12,600	11,700
Postdoctoral appointment	1,900	1,900	2,700	2,200	1,700	1,700	2,200	3,100	2,700	2,400
Percent	21.1	21.4	26.6	21.9	17.1	17.0	22.3	26.5	21.2	20.9
Early career doctorate-holders in nonprofits	6,100	6,200	6,300	6,100	5,800	6,200	8,000	9,300	9,000	7,900
Postdoctoral appointment	1,400	1,200	1,200	1,300	800	700	2,300	2,900	2,500	2,400
Percent	22.3	19.4	19.0	21.9	14.5	11.2	28.3	31.5	28.1	30.5
Early career doctorate-holders in K-12 education and other sectors	1,500	2,300	2,500	2,700	2,900	2,400	2,000	1,800	2,300	1,700

(continued)

Table 5.8 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Postdoctoral appointment	S	300	400	200	200	200	200	100	200	100
Percent	S	13.3	15.3	7.3	7.1	8.2	9.4	7.9	9.9	8.8

S&E science and engineering
S suppressed for reliability; coefficient of variation exceeds 50 %
Notes: Employed includes full time and part time employment. Early career is 5 years or less since doctorate, where years since doctorate is based on academic year. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15). Business/Industry includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Government includes local government, state government, federal government, U.S. military (A13); excludes anyone whose principal employer was educational institution (A14). K-12 education and other sectors includes those responding Other (A13); also includes anyone whose principal employer was educational institution (A14) and whose educational institution was K-12/school system (A15)
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.9 S&E doctorate-holders employed in academe, by broad field of degree and type of institution: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All fields and institutions	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
2-year colleges	6,600	6,900	7,600	8,500	9,600	10,600	11,200	11,500	13,400	14,000
4-year universities	155,300	160,300	168,000	167,900	170,900	175,500	187,200	191,900	210,200	220,100
Medical schools, research institutes, and other institutions	54,800	59,600	62,000	68,500	71,400	82,600	82,200	77,500	79,200	84,200
Science	184,300	192,600	201,800	207,800	212,500	226,600	234,900	233,800	251,700	263,000
2-year colleges	6,200	6,500	7,000	8,100	8,900	9,800	10,300	10,600	12,100	12,800
4-year universities	131,200	135,400	141,800	141,200	142,500	147,200	155,000	158,600	174,200	180,600
Medical schools, research institutes, and other institutions	46,900	50,800	53,000	58,500	61,100	69,700	69,500	64,600	65,400	69,700
Biological/agricultural/ environmental life sciences	61,400	65,000	69,500	72,500	74,700	78,900	82,600	80,400	86,900	92,700
2-year colleges	1,800	1,900	2,100	2,400	2,800	3,100	3,400	3,300	3,400	3,900
4-year universities	32,900	34,500	36,000	35,600	35,300	36,100	39,300	39,500	44,200	45,500
Medical schools, research institutes, and other institutions	26,800	28,600	31,400	34,500	36,500	39,700	39,900	37,600	39,300	43,300
Computer/information sciences	2,500	3,200	3,400	3,700	3,800	5,400	5,900	7,000	7,500	8,500
2-year colleges	D	D	D	D	S	100	100	100	100	200
4-year universities	2,200	2,800	2,900	3,300	3,400	4,700	4,900	5,900	6,400	7,000
Medical schools, research institutes, and other institutions	200	300	400	400	400	600	800	900	900	1,400
Mathematics/statistics	15,300	15,000	17,200	15,400	15,500	17,200	17,700	18,000	19,100	19,600
2-year colleges	500	500	600	600	500	600	700	700	1,000	1,000
4-year universities	13,400	13,100	14,900	13,000	13,100	13,900	14,300	14,900	15,500	16,600
Medical schools, research institutes, and other institutions	1,500	1,500	1,800	1,800	1,800	2,700	2,700	2,400	2,600	2,000
Physical sciences	38,100	39,500	38,400	39,100	39,100	41,600	40,900	41,000	45,400	46,700
2-year colleges	1,700	1,600	1,800	2,000	2,400	2,300	2,400	2,200	2,900	3,100
4-year universities	27,300	28,000	28,800	28,100	28,100	29,100	28,800	29,800	34,200	35,200

(continued)

Table 5.9 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Medical schools, research institutes, and other institutions	9,100	9,900	7,800	9,000	8,700	10,100	9,600	9,100	8,300	8,400
Psychology	24,500	26,600	28,000	29,600	31,000	33,100	35,900	35,100	36,200	37,500
2-year colleges	1,100	1,000	1,300	1,200	1,400	1,700	1,600	2,000	2,100	2,100
4-year universities	17,600	19,100	20,000	20,600	21,200	22,000	25,200	25,400	26,200	27,000
Medical schools, research institutes, and other institutions	5,800	6,500	6,800	7,800	8,400	9,300	9,100	7,700	7,900	8,300
Social sciences	42,500	43,300	45,400	47,500	48,500	50,500	52,000	52,300	56,600	58,000
2-year colleges	1,200	1,500	1,300	1,700	1,800	1,900	2,200	2,300	2,600	2,500
4-year universities	37,800	37,900	39,200	40,700	41,400	41,300	42,500	43,100	47,800	49,300
Medical schools, research institutes, and other institutions	3,600	4,000	4,800	5,200	5,300	7,200	7,300	7,000	6,300	6,200
Engineering	25,000	25,700	26,400	26,200	27,300	28,600	30,500	30,900	33,700	35,800
2-year colleges	300	300	200	200	400	600	500	500	700	700
4-year universities	19,800	19,900	20,800	20,400	21,000	20,900	23,300	23,100	25,300	27,300
Medical schools, research institutes, and other institutions	4,900	5,500	5,300	5,600	6,000	7,100	6,800	7,300	7,700	7,800
Health	7,400	8,400	9,400	10,900	12,100	13,500	15,200	16,100	17,300	19,500
2-year colleges	100	200	300	300	300	200	400	400	500	400
4-year universities	4,300	5,000	5,400	6,400	7,400	7,500	8,900	10,200	10,700	12,300
Medical schools, research institutes, and other institutions	3,000	3,300	3,700	4,300	4,300	5,800	5,900	5,600	6,100	6,700

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D suppressed to avoid disclosure of confidential information
S suppressed for reliability; coefficient of variation exceeds 50 %
Notes: Employed includes full time and part time employment. Part time employment does not exclude those who are part time because they are retired or students (in Chap. 5 of S&E Indicators, these categories of part timers are excluded). Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15)
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.10 Full time employed faculty in academe, by primary work activity: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All institutions	157,700	165,400	171,600	176,400	178,800	174,400	181,500	183,900	195,900	202,400
Research as primary work activity[a]	52,900	55,900	57,000	59,200	61,400	69,400	70,500	70,900	75,700	79,000
Teaching as primary work activity[b]	82,200	87,500	90,700	93,100	91,600	85,000	84,200	87,600	92,100	93,300
Other primary work activities[c]	22,700	22,000	23,900	24,200	25,700	20,100	26,800	25,400	28,100	30,100
Very high research institutions[d]	61,000	62,000	63,700	66,600	66,200	68,800	70,800	71,200	77,100	75,300
Research as primary work activity	32,000	33,400	32,800	35,300	36,500	42,700	44,200	43,800	47,000	46,300
Teaching as primary work activity	20,600	20,500	21,400	21,900	20,000	17,100	15,900	16,400	17,500	16,000
Other primary work activities	8,500	8,100	9,500	9,400	9,800	8,900	10,700	11,000	12,700	13,000
High research institutions[e]	14,700	15,200	15,400	15,000	14,800	14,500	29,200	29,400	31,500	29,600
Research as primary work activity	5,000	5,700	5,700	5,800	5,900	6,600	11,600	12,500	13,100	12,400
Teaching as primary work activity	7,100	7,200	7,500	7,400	6,800	6,000	13,500	13,200	13,700	12,800
Other primary work activities	2,600	2,300	2,200	1,800	2,100	2,000	4,200	3,700	4,700	4,400
Doctoral research institutions[f]	20,400	21,300	21,600	22,300	22,500	21,000	7,500	7,500	8,100	8,200
Research as primary work activity	5,200	5,600	6,200	6,400	6,000	6,600	1,800	1,500	2,000	1,800
Teaching as primary work activity	12,100	13,000	12,700	13,200	13,600	12,300	4,800	4,700	4,700	5,200
Other primary work activities	3,100	2,700	2,700	2,700	2,900	2,100	900	1,400	1,300	1,100
Comprehensive institutions[g]	33,500	35,800	36,800	38,600	39,600	36,900	38,900	39,500	41,200	41,800
Research as primary work activity	3,100	3,300	3,500	3,200	3,400	4,100	3,600	3,400	4,000	4,100
Teaching as primary work activity	26,500	28,800	29,300	30,300	31,300	30,000	31,600	32,400	33,300	33,500

(continued)

Table 5.10 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Other primary work activities	4,000	3,800	4,100	5,100	4,900	2,800	3,700	3,700	3,900	4,200
Other institutions[h]	28,100	31,000	34,000	33,900	35,700	33,200	35,100	36,400	38,000	47,500
Research as primary work activity	7,600	7900	8,900	8,500	9,600	9,400	9,400	9,800	9,600	14,400
Teaching as primary work activity	15,900	18,000	19,700	20,300	20,100	19,600	18,400	20,900	22,900	25,700
Other primary work activities	4,600	5,000	5,400	5,200	6,000	4,300	7,200	5,700	5,500	7,300

S&E science and engineering

[a]Research primary activity includes the following activities: basic research, applied research, development, or design (A30, A31)

[b]Teaching primary activity includes only the teaching activity (A30, A31)

[c]Other primary work activities include all activities other than research and teaching

[d]Very-high research institutions include medical schools and university-affiliated research institutes (A15), and 4-year universities (A15) who are VHRU on the Carnegie classification

[e]High research institutions include medical schools and university-affiliated research institutes (A15), and 4-year universities (A15) who are HRU on the Carnegie classification

[f]Doctoral research institutions include medical schools and university-affiliated research institutes (A15), and 4-year universities (A15) who are DRU on the Carnegie classification

[g]Comprehensive institutions include 4-year universities (A15) who are master's-granting, freestanding schools of engineering, technology, etc., on the Carnegie classification

[h]Other institutions include 4-year universities (A15) other than those listed above on the Carnegie classification; also include medical schools and specialized institutions

Notes: Full time employed is working 35 h or more per week; no part time employed are included. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system or 2-year college (A15). (Respondents from 2-year colleges are excluded from academe due to focus on research in 4-year schools.) For 1993–2001 SDR data: Faculty includes persons employed in academe whose rank is professor, associate professor, or assistant professor, and excludes respondents reporting principal job as postdoc. For 2003–2013 SDR data: Faculty includes persons employed in academe whose type of academic position is teaching faculty or research faculty (A16) and whose rank is professor, associate professor, or assistant professor (A17). Primary work activity based on activity with most hours reported at A31

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.11 S&E doctorate-holders employed in academe, by sex and rank or position: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All fields and ranks or positions	216,700	226,800	237,500	244,900	251,800	268,700	280,600	280,900	302,700	318,300
Male	170,400	173,400	177,700	179,700	180,200	188,300	188,900	185,500	195,600	201,700
Female	46,300	53,400	59,800	65,200	71,600	80,400	91,800	95,400	107,100	116,700
Full time senior faculty[a]	122,200	127,800	132,200	136,700	137,000	130,000	131,400	136,600	145,700	150,300
Male	104,800	107,500	109,700	110,600	108,300	99,900	98,700	100,000	105,000	106,300
Female	17,400	20,400	22,600	26,100	28,600	30,000	32,700	36,600	40,700	43,900
Full time junior faculty[b]	38,900	41,100	42,700	43,600	46,100	48,300	54,300	51,700	55,200	57,400
Male	26,600	26,800	27,200	27,700	28,500	29,200	31,700	30,100	30,900	31,800
Female	12,300	14,200	15,500	15,900	17,600	19,100	22,600	21,600	24,300	25,600
Other full time positions[c]	25,900	32,000	30,300	33,100	36,100	51,500	48,000	50,600	53,800	61,300
Male	18,600	22,400	20,300	22,900	23,900	35,300	30,800	31,200	32,200	36,100
Female	7,300	9,600	9,900	10,200	12,200	16,200	17,100	19,400	21,600	25,200
Full time postdocs[d]	19,400	17,000	18,100	17,900	17,000	15,900	22,700	17,900	22,400	21,000
Male	14,400	11,500	11,800	11,000	10,400	10,000	13,500	11,100	13,600	12,700
Female	5,000	5,500	6,300	6,900	6,600	5,900	9,100	6,900	8,700	8,400

(continued)

Table 5.11 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Part time positions[e]	10,400	8,900	14,300	13,600	15,700	23,000	24,200	24,000	25,600	28,400
Male	6,100	5,200	8,800	7,400	9,100	13,900	14,100	13,100	13,900	14,800
Female	4,300	3,700	5,600	6,200	6,500	9,200	10,100	10,900	11,700	13,600

S&E science and engineering

[a]For 1993–2001 SDR data: Full time senior faculty includes full time employed in academe whose faculty rank was professor or associate professor; excludes respondents whose principal job was postdoc. For 2003–2013 SDR data: Full time senior faculty includes full time employed in academe whose type of academic position was teaching faculty or research faculty (A16) and whose faculty rank was professor or associate professor (A17)

[b]For 1993–2001 SDR data: Full time junior faculty includes full time employed in academe whose faculty rank was assistant professor; excludes respondents whose principal job was postdoc. For 2003–2013 SDR data: Full time junior faculty includes full time employed in academe whose type of academic position was teaching faculty or research faculty (A16) and whose faculty rank was assistant professor (A17)

[c]For 1993–2001 SDR data: Other full time positions include those full time employed in academe whose faculty rank is instructor, lecturer, adjunct faculty, other-specify, or not applicable (at institution or for position); excludes respondents whose principal job is postdoc. For 2003–2013 SDR data: Other full time positions include those full time employed in academe whose type of academic position was president/provost/chancellor, dean, adjunct faculty, research assistant, teaching assistant, or other position (A16); also includes those full time employed in academe who responded research faculty or teaching faculty (A16) and responded instructor, lecturer, other-specify, or not applicable (A17)

[d]For 1993–2001 SDR data: Postdocs include those full time employed in academe whose principal job is postdoc (regardless of faculty rank); part time postdocs are not counted here. For 2003–2013 SDR data: Postdocs include those full time employed in academe whose type of academic position was postdoc (A16); part time postdocs are not counted here

[e]Part time positions include those part time employed in academe regardless of response to position (A16) or rank (A17); part time postdocs are counted here. Part time employment does not exclude those who are part time because they are retired or students (in Chap. 5 of S&E Indicators, these categories of part timers are excluded)

Notes: Full time employment is working 35 h or more per week; part time employment is less than 35 h per week. Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.12 Early career S&E doctorate-holders employed in academe by field of degree and tenure status: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All fields	47,000	50,400	54,000	52,400	52,800	58,900	62,800	61,900	68,400	58,700
Tenured or on tenure track[a]	21,200	20,800	21,800	20,500	20,700	25,900	24,700	26,900	26,500	20,100
Postdoc appointment[b]	14,100	14,600	16,000	16,000	15,200	13,800	21,000	16,400	20,600	18,200
Not on tenure track[c]	11,700	15,000	16,200	15,800	17,000	19,300	17,200	18,600	21,300	20,300
Science	38,300	41,300	44,500	43,900	43,900	48,100	50,500	49,900	55,000	46,800
Tenured or on tenure track	16,100	15,900	16,900	16,100	16,200	20,200	18,900	20,700	20,600	15,300
Postdoc appointment	12,700	13,100	14,300	14,600	14,000	12,300	17,600	13,900	17,300	15,400
Not on tenure track	9,500	12,300	13,300	13,100	13,800	15,500	14,100	15,300	17,100	16,100
Biological/agricultural/environmental life sciences	13,500	15,100	16,600	17,300	17,000	17,700	18,300	18,100	20,600	18,000
Tenured or on tenure track	3,000	3,200	3,500	3,500	3,300	4,100	3,100	4,000	4,000	2,700
Postdoc appointment	7,500	7,500	8,900	9,700	9,200	8,200	10,400	8,900	10,300	9,600
Not on tenure track	3,000	4,400	4,200	4,200	4,500	5,500	4,800	5,200	6,300	5,700
Computer/information sciences	1,500	1,600	1,500	1,400	1,200	1,900	1,800	2,300	2,300	1,900
Tenured or on tenure track	1,200	1,300	1,200	1,000	800	1,200	1,400	1,600	1,500	1,200
Postdoc appointment	100	100	100	100	D	S	100	200	300	100
Not on tenure track	200	200	200	300	300	600	400	500	500	600
Mathematics/statistics	2,600	2,500	2,900	2,200	2,600	3,000	3,300	3,500	3,700	3,300
Tenured or on tenure track	1,700	1,600	1,600	1,200	1,300	2,000	1,900	2,100	2,100	1,500
Postdoc appointment	400	400	500	500	700	400	900	500	600	600
Not on tenure track	600	600	900	500	600	600	400	800	900	1,100
Physical sciences	7,900	8,700	8,100	7,100	7,400	7,600	8,200	7,800	9,600	8,000
Tenured or on tenure track	2,300	2,100	2,400	2,100	2,600	3,000	2,700	2,500	2,800	1,900
Postdoc appointment	3,800	4,100	3,300	3,100	2,600	2,300	3,600	3,000	4,300	3,700
Not on tenure track	1,900	2,500	2,500	2,000	2,200	2,300	1,900	2,300	2,400	2,500
Psychology	5,100	5,700	6,400	6,700	6,800	7,800	8,600	7,900	7,700	5,900
Tenured or on tenure track	2,100	2,600	2,600	2,600	2,600	3,000	3,200	3,400	3,100	2,100

(continued)

Table 5.12 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Postdoc appointment	600	800	1,100	1,000	1,000	900	1,700	1,100	1,000	800
Not on tenure track	2,300	2,300	2,800	3,200	3,100	3,900	3,600	3,400	3,600	3,000
Social sciences	7,700	7,800	8,900	9,000	8,900	10,000	10,300	10,400	11,100	9,700
Tenured or on tenure track	5,700	5,200	5,600	5,800	5,500	6,900	6,600	7,000	7,100	6,000
Postdoc appointment	400	300	500	400	400	400	800	300	700	500
Not on tenure track	1,600	2,400	2,800	2,900	3,000	2,700	3,000	3,100	3,300	3,200
Engineering	6,200	6,200	6,200	5,100	5,200	6,400	7,600	7,300	8,400	7,700
Tenured or on tenure track	3,500	3,100	3,100	2,600	2,600	3,200	3,000	3,500	3,300	3,000
Postdoc appointment	1,200	1,200	1,300	1,000	800	1,100	2,900	2,000	2,800	2,300
Not on tenure track	1,500	1,900	1,800	1,500	1,800	2,100	1,700	1,800	2,300	2,400
Health	2,500	2,900	3,300	3,400	3,700	4,500	4,700	4,700	4,900	4,100
Tenured or on tenure track	1,700	1,800	1,800	1,900	1,900	2,500	2,800	2,700	2,600	1,800
Postdoc appointment	200	300	400	300	400	400	500	500	500	500
Not on tenure track	700	800	1,100	1,200	1,400	1,700	1,400	1,500	1,900	1,800

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D suppressed to avoid disclosure of confidential information
S suppressed for reliability; coefficient of variation exceeds 50 %
[a]Tenured or on tenure track includes individuals employed in academe responding either Tenured or On tenure track but not tenured (A18)
[b]For 1993-2001 SDR data: Postdoc appointment includes those individuals employed in academe responding Not on tenure track, Not applicable: no tenure system at my institution, or Not applicable: no tenure system for my position; and reporting Postdoc as their principal job. For 2003-2013 SDR data: Postdoc appointment includes those individuals employed in academe responding Not on tenure track, Not applicable: no tenure system at my institution, or Not applicable: no tenure system for my position (A18); and reporting Postdoc as their academic position (A16)
[c]Not on tenure track includes individuals employed in academe responding Not on tenure track, Not applicable: no tenure system at my institution, or Not applicable: no tenure system for my position (A18), and excludes those individuals reporting Postdoc as academic position (A16, or as reponse to principal job)
Notes: Early career is 5 years or less since doctorate, where years since doctorate is based on academic year. Employed includes full time and part time employment. Part time employment does not exclude those who are part time because they are retired or students (in Chap. 5 of S&E Indicators, these categories of part timers are excluded). Academe includes anyone whose principal employer was educational institution (A14) and whose educational institution was either 2-year, 4-year, medical school, or affiliated research institute (A15); excludes anyone whose institution was K-12/school system (A15)
Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.13 S&E doctorate-holders employed in business by broad field of doctorate and percentage who are self-employed: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All fields employed in business	169,500	175,300	190,100	216,100	227,400	223,700	232,500	253,200	265,600	276,500
Self-employed business owners[a]	41,100	41,900	36,500	45,400	45,200	64,600	70,900	77,800	82,000	84,600
Percent of total	24.3	23.9	19.2	21.0	19.9	28.9	30.5	30.7	30.9	30.6
Science	123,500	126,700	135,300	152,600	160,200	157,700	163,100	175,000	182,400	187,200
Self-employed business owners	35,300	36,400	31,400	38,300	38,800	53,100	57,600	61,700	64,900	67,100
Percent of total	28.5	28.7	23.2	25.1	24.2	33.7	35.3	35.3	35.6	35.8
Biological/agricultural/ environmental life sciences	29,800	31,400	32,700	39,100	42,400	41,700	44,200	48,800	52,100	54,000
Self-employed business owners	5,800	6,300	5,300	7,200	6,800	10,100	11,500	13,500	13,800	15,100
Percent of total	19.4	20.1	16.0	18.3	16.0	24.3	26.0	27.8	26.4	27.9
Computer/information sciences	2,400	2,900	4,100	5,200	6,300	5,800	6,600	7,800	10,000	11,400
Self-employed business owners	100	200	200	300	300	800	900	1,000	1,300	1,500
Percent of total	4.8	6.2	6.1	5.7	5.1	13.8	13.7	12.5	12.6	13.5
Mathematics/statistics	5,600	5,600	7,100	7,700	8,100	8,400	8,300	9,100	9,700	9,800
Self-employed business owners	900	800	700	800	800	1,300	2,100	1,700	1,400	1,700
Percent of total	15.8	13.8	9.7	10.1	10.3	15.8	25.3	18.8	14.3	17.1
Physical sciences	46,300	46,700	50,000	54,100	55,000	53,000	52,800	55,000	54,400	55,200
Self-employed business owners	4,400	5,100	4,500	4,700	4,900	8,800	9,300	10,000	11,000	10,500
Percent of total	9.5	10.8	9.0	8.7	9.0	16.6	17.6	18.1	20.3	19.0
Psychology	29,100	29,700	30,900	33,700	35,700	36,000	37,800	39,800	40,900	41,300
Self-employed business owners	19,900	20,100	17,500	20,900	21,900	26,500	27,900	29,100	30,400	31,100
Percent of total	68.5	67.6	56.8	62.1	61.3	73.8	73.7	73.2	74.4	75.3

(continued)

Table 5.13 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Social sciences	10,400	10,400	10,500	12,700	12,800	12,800	13,500	14,700	15,300	15,500
Self-employed business owners	4,200	4,000	3,200	4,500	4,100	5,500	6,000	6,400	7,000	7,200
Percent of total	40.5	38.5	30.8	35.3	31.7	42.7	44.2	43.7	45.8	46.5
Engineering	42,300	44,700	50,600	58,500	61,500	60,400	63,500	71,300	76,000	82,200
Self-employed business owners	4,800	4,400	4,100	5,500	4,900	9,200	11,100	13,200	14,000	14,500
Percent of total	11.3	9.9	8.2	9.3	8.0	15.3	17.5	18.5	18.4	17.6
Health	3,600	3,800	4,200	5,100	5,700	5,700	5,900	6,800	7,300	7,100
Self-employed business owners	1,100	1,000	900	1,600	1,500	2,300	2,200	2,900	3,100	3,100
Percent of total	29.5	27.2	22.2	31.4	26.1	41.0	37.6	42.4	42.3	42.9

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[a]Self-employed business owner includes self-employed in non-incorporated business and self-employed in incorporated business (A13)

Notes: Employed includes full time and part time employment. Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.14 S&E doctorate-holders employed in business by broad field of doctorate and employer size: 1993–2013

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
All fields employed in business	na	175,300	190,100	216,100	227,400	223,700	232,500	253,200	265,600	276,500
<100 employees[a]	na	68,400	71,900	82,900	88,400	92,500	97,400	106,300	109,900	112,700
100–999 employees	na	22,300	26,800	30,300	32,800	29,600	28,900	31,700	31,900	32,800
1000–24,999 employees	na	84,600	91,400	102,900	106,200	48,300	51,300	57,400	61,800	65,000
25,000 or more employees	na	na	na	na	na	53,300	55,000	57,800	62,100	66,100
Science	na	126,700	135,300	152,600	160,200	157,700	163,100	175,000	182,400	187,200
<100 employees	na	55,800	58,300	66,100	70,000	73,000	76,300	82,400	84,900	86,900
100–999 employees	na	16,200	18,900	21,500	22,800	20,700	20,300	22,100	22,000	21,900
1000–24,999 employees	na	54,700	58,100	65,000	67,400	30,700	32,700	35,600	38,100	39,400
25,000 or more employees	na	na	na	na	na	33,300	33,800	34,900	37,400	39,000
Biological/agricultural/ environmental life sciences	na	31,400	32,700	39,100	42,400	41,700	44,200	48,800	52,100	54,000
<100 employees	na	12,200	12,100	14,700	16,300	16,400	17,900	20,200	21,300	21,900
100–999 employees	na	5,700	6,100	7,400	7,700	7,700	7,600	8,100	7,700	7,400
1000–24,999 employees	na	13,600	14,600	17,100	18,400	9,800	10,400	11,500	12,600	13,500
25,000 or more employees	na	na	na	na	na	8,000	8,300	9,100	10,600	11,200
Computer/information sciences	na	2,900	4,100	5,200	6,300	5,800	6,600	7,800	10,000	11,400
<100 employees	na	600	900	1,200	1,500	1,600	1,600	1,900	2,500	2,700
100–999 employees	na	400	600	800	1,100	700	600	1,000	1,000	1,000
1000–24,999 employees	na	1,900	2,600	3,200	3,600	1,200	1,900	1,900	2,800	2,500
25,000 or more employees	na	na	na	na	na	2,300	2,500	2,900	3,700	5,200
Mathematics/statistics	na	5,600	7,100	7,700	8,100	8,400	8,300	9,100	9,700	9,800
<100 employees	na	1,600	1,900	2,100	2300	2,300	2,500	2,500	2,400	2,500
100–999 employees	na	700	1,100	1,400	1,400	1,200	1,000	1,200	1,400	1,500

(continued)

Table 5.14 (continued)

	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
1000–24,999 employees	na	3,400	4,100	4,300	4,400	2,000	2,000	2,400	3,000	2,800
25,000 or more employees	na	na	na	na	na	2,900	2,800	2,900	3,000	3,100
Physical sciences	na	46,700	50,000	54,100	55,000	53,000	52,800	55,000	54,400	55,200
<100 employees	na	11,300	12,700	14,000	14,300	15,700	15,500	17,000	17,400	17,800
100–999 employees	na	5,800	7,500	7,900	8,300	7,100	7,000	7,400	7,100	7,500
1000–24,999 employees	na	29,500	29,800	32,200	32,300	13,700	13,700	14,600	14,100	15,000
25,000 or more employees	na	na	na	na	na	16,500	16,600	16,000	15,700	15,000
Psychology	na	29,700	30,900	33,700	35,700	36,000	37,800	39,800	40,900	41,300
<100 employees	na	23,800	24,500	26,900	28,600	29,800	30,800	32,600	32,700	33,600
100–999 employees	na	2,200	2,100	2,200	2,400	1,800	2,000	2,100	2,600	2,500
1000–24,999 employees	na	3,700	4,300	4,600	4,700	2,200	2,600	3,100	3,200	3,100
25,000 or more employees	na	na	na	na	na	2,200	2,400	2,000	2,300	2,100
Social sciences	na	10,400	10,500	12,700	12,800	12,800	13,500	14,700	15,300	15,500
<100 employees	na	6,200	6,300	7,300	6,800	7,300	8,000	8,200	8,500	8,400
100–999 employees	na	1,500	1,500	1,700	2,000	2,300	2,200	2,300	2,200	2,100
1000–24,999 employees	na	2,700	2,700	3,700	3,900	1,800	2100	2,200	2,400	2,600
25,000 or more employees	na	na	na	na	na	1,400	1,300	2,000	2,100	2,400
Engineering	na	44,700	50,600	58,500	61,500	60,400	63,500	71,300	76,000	82,200
<100 employees	na	10,900	12,000	14,400	15,700	16,600	18,100	20,600	21,400	22,200
100–999 employees	na	5,600	7,200	8,200	9,200	8,200	7,900	8,900	9,000	10,000
1000–24,999 employees	na	28,200	31,400	35,900	36,500	16,900	17,600	20,300	22,300	24,200
25,000 or more employees	na	na	na	na	na	18,600	19,900	21,600	23,300	25,800
Health	na	3,800	4,200	5,100	5,700	5,700	5,900	6,800	7,300	7,100
<100 employees	na	1,700	1,600	2,400	2,700	2,900	3,000	3,300	3,600	3,600

100–999 employees	na	500	700	600	700	700	700	700	900	800
1000–24,999 employees	na	1,600	1,900	2,000	2,200	700	1,000	1,500	1,500	1,400
25,000 or more employees	na	na	na	na	na	1,400	1,300	1,400	1,400	1,300

na not applicable; question was not asked. *S&E* science and engineering

[a]Size of employer

Notes: Employed includes full time and part time employment. Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14)

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993–2013

Table 5.15 S&E doctorate-holders employed in business by broad field of doctorate and employer size, according to research status: 1993, 2003, 2013

	1993			2003			2013		
	All employed in business	Researcher[a]	Percent	All employed in business	Researcher	Percent	All employed in business	Researcher	Percent
All fields employed in business	na	na	na	223,700	132,700	59.3	276,500	165,100	59.7
<100 employees[b]	na	na	na	92,500	39,500	42.7	112,700	49,600	44.0
100–999 employees	na	na	na	29,600	18,100	61.2	32,800	20,800	63.4
1000–24,999 employees	na	na	na	48,300	34,200	70.9	65,000	45,900	70.7
25,000 or more employees	na	na	na	53,300	40,800	76.6	66,100	48,800	73.8
Science	na	na	na	157,700	84,800	53.8	187,200	100,100	53.5
<100 employees	na	na	na	73,000	27,400	37.5	86,900	33,500	38.6
100–999 employees	na	na	na	20,700	12,000	58.0	21,900	13,100	59.6
1000–24,999 employees	na	na	na	30,700	20,600	67.2	39,400	26,400	67.1
25,000 or more employees	na	na	na	33,300	24,800	74.4	39,000	27,000	69.2
Biological/agricultural/ environmental life sciences	na	na	na	41,700	24,800	59.4	54,000	32,000	59.2
<100 employees	na	na	na	16,400	7,700	47.3	21,900	11,200	51.1
100–999 employees	na	na	na	7,700	4,400	57.0	7,400	4,100	55.2
1000–24,999 employees	na	na	na	9,800	6,700	68.8	13,500	9,000	66.6
25,000 or more employees	na	na	na	8,000	6,000	75.2	11,200	7,700	68.8
Computer/information sciences	na	na	na	5,800	4,100	71.2	11,400	7,900	69.3
<100 employees	na	na	na	1,600	900	57.8	2,700	1,600	60.9

100–999 employees	na	na	na	700	400	54.8	1,000	700	63.3
1000–24,999 employees	na	na	na	1,200	900	76.1	2,500	1,800	73.3
25,000 or more employees	na	na	na	2,300	1,900	83.4	5,200	3,800	73.0
Mathematics/statistics	na	na	na	8,400	5,300	63.3	9,800	6,400	65.3
<100 employees	na	na	na	2,300	1,400	61.3	2,500	1,400	57.8
100–999 employees	na	na	na	1,200	800	68.5	1,500	1,100	72.6
1000–24,999 employees	na	na	na	2,000	1,200	57.7	2,800	1,900	66.6
25,000 or more employees	na	na	na	2,900	1,900	66.6	3,100	2,100	66.5
Physical sciences	na	na	na	53,000	37,200	70.2	55,200	38,300	69.3
<100 employees	na	na	na	15,700	9,200	58.9	17,800	10,300	58.1
100–999 employees	na	na	na	7,100	4,900	68.3	7,500	5,600	74.5
1000–24,999 employees	na	na	na	13,700	9,800	71.9	15,000	10,900	72.9
25,000 or more employees	na	na	na	16,500	13,300	80.1	15,000	11,500	76.3
Psychology	na	na	na	36,000	7,300	20.3	41,300	8,200	20.0
<100 employees	na	na	na	29,800	4,600	15.5	33,600	5,100	15.2
100–999 employees	na	na	na	1,800	500	26.2	2,500	700	29.5
1000–24,999 employees	na	na	na	2,200	1,200	52.2	3,100	1,400	46.4
25,000 or more employees	na	na	na	2,200	1,100	48.4	2,100	1,000	45.9
Social sciences	na	na	na	12,800	6,100	47.4	15,500	7,300	47.1
<100 employees	na	na	na	7,300	3,500	47.5	8,400	3,900	45.8

(continued)

Table 5.15 (continued)

	1993			2003			2013		
	All employed in business	Researcher[a]	Percent	All employed in business	Researcher	Percent	All employed in business	Researcher	Percent
100–999 employees	na	na	na	2,300	1,200	49.7	2,100	1,000	46.2
1000–24,999 employees	na	na	na	1,800	800	46.7	2,600	1,500	56.4
25,000 or more employees	na	na	na	1,400	600	44.0	2,400	1,000	42.4
Engineering	na	na	na	60,400	45,200	74.9	82,200	61,100	74.3
<100 employees	na	na	na	16,600	11,100	67.0	22,200	14,500	65.4
100–999 employees	na	na	na	8,200	5,800	70.5	10,000	7,300	72.8
1000–24,999 employees	na	na	na	16,900	13,200	78.3	24,200	18,500	76.5
25,000 or more employees	na	na	na	18,600	15,000	80.7	25,800	20,700	80.4
Health	na	na	na	5,700	2,700	48.3	7,100	3,900	55.2
<100 employees	na	na	na	2,900	1,000	35.3	3,600	1,500	41.5
100–999 employees	na	na	na	700	300	47.2	800	400	48.9
1000–24,999 employees	na	na	na	700	400	54.0	1,400	900	67.7
25,000 or more employees	na	na	na	1,400	1,000	73.2	1,300	1,100	82.3

na not applicable; question was not asked. *S&E* science and engineering

[a]Researchers are doctorate-holders reporting primary or secondary work activity as basic research, applied research, development, or design (A30, A31)

[b]Size of employer

Notes: Employed includes full time and part time employment. Business includes for-profit company, self-employed in non-incorporated business, self-employed in incorporated business (A13); excludes anyone whose principal employer was educational institution (A14). Employer size variable was not requested on 1993 survey

Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1993, 2003, 2013

References

Council of Graduate Schools and Educational Testing Service (2010) The path forward: the future of graduate education in the United States. Report from the commission on the future of graduate education in the United States. Educational Testing Service, Princeton, NJ

Kezar A, Maxey D (2013) The changing academic workforce. Trusteeship 21(3), May/June. http://agb.org/trusteeship/2013/5/changing-academic-workforce

National Science Foundation (2013) National Center for Science and Engineering Statistics, Survey of Doctorate Recipients: 2013. http://ncsesdata.nsf.gov/doctoratework/2013/. Accessed 12 Apr 2016

National Science Foundation (2014) Science and Engineering Indicators 2014. Arlington, VA (NSB 14-01). http://www.nsf.gov/statistics/seind14/index.cfm/chapter-3/c3s2.htm#s5

National Science Foundation (2015) National Center for Science and Engineering Statistics. Doctorate recipients from US Universities: 2014, Special Report NSF 16-300. Arlington, VA. http://www.nsf.gov/statistics/2016/nsf16300/. Accessed 12 Apr 2016

President's Council of Advisors on Science and Technology (PCAST) (2012) Report to the President: engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Selfa LA, Proudfoot S (2014) Unemployment among doctoral scientists and engineers remains below the national average in 2013. National Science Foundation (NSF 14-317), Arlington, VA. http://www.nsf.gov/statistics/infbrief/nsf14317/

SESTAT Data Tool (2016) Scientists and Engineers Statisticak Data System. http://ncsesdata.nsf.gov/datadownload/. Accessed 12 Apr 2016

US Census Bureau (2013) Educational attainment in the United States: 2013—detailed tables. http://www.census.gov/hhes/socdemo/education/data/cps/2013/tables.html

US Bureau of Labor Statistics (2013) May 2013 national occupational employment and wage estimates: United States. http://www.bls.gov/oes/current/oes_nat.htm#00-0000

Pecuniary and Scientific Motives as Drivers of PhD Careers: Exploring the Evidence from Belgium

6

Karl Boosten and André Spithoven

6.1 Introduction

The central theme in our chapter revolves around the question of why university graduates choose to start a doctorate. Do they decide to write a doctoral dissertation to improve their competencies and skills so they have better access to high-level, better-paid jobs on the labor market? Or is this decision also based on intrinsic motivations, such as a passion for scientific research and its inherently problem-solving nature? To borrow some of the terminology introduced by Lam (2011), we could formulate our research question as follows: are university graduates motivated by financial rewards ('gold'), academic status ('ribbon') or scientific challenges ('puzzle')? In the rest of the chapter, we will focus on the gold and the puzzle; we did not take into account a variable for ribbon in our analyses. This was partly dictated by the absence of a direct, reliable proxy but also by a concern not to make our models overly complex. The measurement of extrinsic, pecuniary motivation can be done by making use of the variable salary. However, salary can also have a broader interpretation given that upward movements on the hierarchical ladder of organizations are mostly accompanied by salary increases. According to the principles of human capital theory, employees acquire knowledge, competencies and skills on the jobs they perform and this accumulation of human capital is partly capitalized in their salary level. Topel (1991), for example, found that 10 years of seniority increases salaries in general by more than 25 %.

To distinguish between doctorate holders conducting research in their daily professional activities and those who are no longer involved in research activities, we relied on the definition formulated in the model questionnaire of the OECD. Based on the guidelines explicated in this manual, researchers are defined as professionals engaged in the conception or creation of new knowledge, products,

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processes, methods and systems and also in the management of the projects concerned (Auriol et al. 2012).

6.2 Literature

6.2.1 PhD Careers in Higher Education and Industry

Although the OECD's model questionnaire covers a broad range of economic sectors (business enterprise sector or industry, government sector, private non-profit sector, higher education and other education sectors), we limit our analyses to the higher education and industry sectors. Both sectors employ the majority of doctorate holders and when investigating the flows of doctorate holders across sectors in time, we notice a substitution effect between both sectors. At the beginning of their careers most doctorate holders (nearly 40 %) are working at a university, while 10 years later this number dwindles to 30 % (Boosten et al. 2014). This difference in PhD graduates' sector of employment can be mainly attributed to a shift in employment from academia to business. As will become clear from our analyses, we will try to clarify the factors explaining this shift. This brings us to discuss the gaps not yet addressed in the existing literature and to which we aim to contribute. Most of the research policy literature is about the collaboration between the academic and business sectors. This growing intertwinement is considered as beneficial for both sectors. Herrera et al. (2010), for example, demonstrate how the flow of knowledge between universities and firms has a positive effect on the inputs (the internal and external expenditures of a firm) and the outputs (patent activity of a firm) of the innovation process within firms.

In addition to an established advantageous effect of firms' cooperation with academia, there is a vast literature on the ways the career composition of academic researchers influences their productivity. Dietz and Bozeman (2005) for example show how academic researchers whose interests purely centre on basic research differ in productivity from their colleagues who also engage in industrial collaboration. The productivity of researchers with a purely academic approach in science is more associated with the writing of publications in scientific journals, while the productivity of academic researchers engaging in industrial projects is more related to the publication of patents.

Not only does the career composition of researchers appear to be a determining factor in explaining the exchange of knowledge between universities and firms, but higher-level institutional features also play an essential role. Several researchers found a positive relationship between faculty quality and patent productivity (Coupé 2003; Geuna and Nesta 2006; Van Looy et al. 2004). According to Perkmann et al. (2011) the involvement of academic staff in industrial activities such as collaborative research, contract research and consulting differs across disciplines. In technology-oriented disciplines the quality of the faculty's research is positively related to the industrial involvement of academic researchers, whereas in social sciences the faculty's research quality is negatively associated with industry involvement. D'Este and Patel (2007) mention several other institutional factors positively influencing university-industry partnerships: the scale of research resources (Schartinger et al. 2001), the quality of the research conducted by the university (Mansfield and Lee 1996; Tornquist and Kallsen 1994), the mission of the university, the presence of effective technology transfer offices, and the presence of R&D intensive firms in the locality (Friedman and Silberman 2003; Siegel et al. 2003).

Individual characteristics can also be helpful in explaining the mutual transmission of knowledge between universities and private firms. For example, the labor position of the academic researcher can have an influence on his/her involvement with industry: tenured and senior researchers are more engaged in industrial activities (Bozeman and Gaughan 2007). Boardman and Ponomariov (2009) give a list of personal and professional attributes that are positively related to industrial research collaboration: number of industry grants, affiliation with a university research centre, number of graduate students supported through grants, tenure status, and scientific values. D'Este and Patel (2007) show how interactions differ according to individual attributes of the university researcher: previous experience in research collaborations with industry (positive effect), the amount of public funding for non-collaborative research (no influence), age (negative effect), academic status (positively significant), and patenting activities (positively significant). Zucker et al. (2002) consider the labor mobility of public researchers as a function of the quality of the scientific work of the researcher (measured as scientific citations) and the reservation salary of the researcher.

Despite this rich literature on the determinants of university-industry collaboration, limited attention has been given to differences in career paths between researchers employed by universities and those working in industry. According to our analyses we found several significant differences in employment situation between both types of careers, which imply that it is worthwhile to consider the two careers as fundamentally different career choices.

In the next section of this chapter, we give an overview of the relevant literature with regard to the factors determining the career paths of individual PhDs. More specifically, we have selected all factors from the OECD's model questionnaire which might have a relation with one of the two motivations (pecuniary or scientific) constituting the career choices of doctorate holders. The following factors are taken into account: involvement in research activities, gender, age, experience, scientific discipline of the doctoral degree, current occupation, type of labor contract (fixed-term or indeterminate/part-time or full-time) and past job mobility. To position our explorative analyses against a theoretical background, we searched for leads in working papers and journal articles that discuss each of these career determining elements.

6.2.2 Salaries and PhD Careers

This section will survey the literature on all the selected variables and how they are related to salary. Salary is here considered as an extrinsic motivational factor in career choices and as an element reflecting the level of professional attainment in the job market. Seven predictors of salary will be reviewed.

First, to the best of our knowledge the existent literature on salaries does not mention specific findings demonstrating that workers conducting research earn higher or lower salaries than other occupational categories. With regard to the salary growth ratio of knowledge workers, Møen (2005) examined the salary evolution of technical staff in R&D-intensive firms. This occupational category consists of workers who in their daily working activities are involved in the management of research projects. He found that this particular category of highly specialized workers earns a lower salary at the beginning of their career and that by means of accumulating knowledge and experience on the job, their salaries adjust to the level of expertise and excellence they gained throughout their career. Our analyses point out that researchers are significantly better paid in higher education than non-researchers. However, being involved in research projects appears to have no significant effect on the salary for employees in the business sector.

Second, the gender salary gap has become smaller over the past decades (Blau and Kahn 1996, 2000; Arulampalam et al. 2007). Nevertheless, studies show that women still earn about 20 % less than men at the median (Antonczyk et al. 2010). Certain researchers (Blau and Kahn 1997) attribute the decline of the gender salary gap to skill-based technological changes. Because of an important increase in the number of women graduating in higher education over the past decades, skill-based technological changes had a more pronounced positive effect on their salary levels. Given that doctorate holders constitute the most specialized segment of the labor market, our analyses still reveal the existence of a significant difference in earnings based on gender. Although skill-based technological changes help to narrow the gap, they are not sufficient to level salary differentials between men and women.

Royalty (1998) explains differences in salary levels between sexes by means of differences in job turnover. She refers to a range of studies, from which she distils four reasons that explain her viewpoint. To begin with, women more often than men leave and re-enter the workforce, this causes a decline in human capital, which in turn suppresses the probability of earning a higher salary (Mincer and Polachek 1974; Corcoran 1979; Corcoran and Duncan 1979; Gronau 1988). Next, women are expected to stay in a job for a shorter period than men, but because of fixed training and other personnel costs, employers are less inclined to pay equal salaries (Donohue 1988). Moreover, although job matching and job searching models link turnover with salary progress, turnover is constrained for women because of their spouse's job location and the birth of children (Royalty 1993; Keith and McWilliams 1995). Finally, firms may be inclined to offer less training and opportunities to enhance human capital to women because of higher job turnover rates (Barron et al. 1993).

Other authors (e.g. Munasinghe et al. 2008) focus on job tenure and labor market experience as explanatory factors for gender salary differentials. The salary return from job tenure is substantially lower for women than men, but the salary return from experience is higher for women than men. This effect is more pronounced for more educated women. The difference in salary return between men and women can be explained by the fact that women are less attached to their job than men: women are more likely to quit their jobs, they receive less company training and in general expect to be out of the labor force for a certain time for family related matters. The impact of career interruptions related to child care on salary has been confirmed in several studies: women with children earn less than childless women (e.g. Waldfogel 1997). Several hypotheses are presented: employers discriminate women with children, during maternity leave women cannot maintain the same rhythm of human capital building as women who stay in the workforce, unobserved heterogeneity between women with and without children, women with children prefer other types of jobs and employment sectors compared to women without children (Felfe 2012). Our analysis partly reflects these findings: female doctorate holders in our sample have less experience than male doctorate holders and experience has a significant impact on salary for both sectors (business and higher education). Further analysis should be conducted to clarify the impact of job tenure and experience on salary return.

Third, the effect of experience on salary depends on which type of experience is taken into account. Two types of seniority are in general considered in salary studies: job experience i.e. the number of years of working experience in a given job and labor market, and the total number of years spent in the labor market. Topel (1991) found a strong correlation between experience and salaries: 10 years of seniority raises salaries by more than 25 %. Figures presented by Altonji and Williams (2005) mitigate this strong relation, however: their study showed a more modest effect of job experience on salaries (10 % over 10 years) but a larger effect of general labor market experience. Williams (2009) repeated his previous research and found an even smaller effect of job experience (tenure) on salaries (1 % over the first 10 years on the job) and a large impact of general labor market experience (60 % over 30 years). Besides these general conclusions, individual and job match heterogeneity explain an important part of the variance in salaries. Moreover, employment sector and occupation can act as intermediate factors modelling the relation between seniority and salaries. Some skills are productivity enhancing and consequently generate higher salaries within particular sectors of the labor market. Skills have an impact on salaries at the level of the sector or the occupation, but not at firm level. Our results are more in line with the most recent studies concerning the impact of experience on salaries: in both sectors under investigation, we discerned a significant influence of experience on the level of salary earned, but this effect was rather limited in its range. Other factors such as gender, age and occupation weigh more on salaries than experience.

Fourth, we assumed a relation between the scientific discipline of the PhD and the salary earned. We could not find any studies directly examining the relation between these two elements. However, because of an indirect impact of the scientific discipline on occupation and employment sector, several studies show how the preference of the doctorate holder for a specific scientific field determines his/her career choices after graduation. Fox and Stephan (2001) for example prove that computer scientists, chemists and electrical engineers are most likely to be employed in jobs in industry or government, while PhD holders in microbiology and physics are least likely to be employed in industry or government.

Enders (2002) compared the employment sector of doctorate holders 1 year and 10 years after graduation. One year after graduation, PhD holders in biology, German studies and mathematics more often pursue a career in higher education than those in social sciences, business studies/economics and electrical engineering. Comparison of the two cohorts in time (1 year after graduation versus 10 years after graduation) showed that the importance of employment in the public sector decreases for some disciplines but not for all. Public sector employment decreases among doctorate holders from business studies/economics and electrical engineering, which is mainly due to decreasing employment opportunities in the higher education sector. The decrease in public sector employment is strong for doctorate holders with a degree in German studies and mathematics.

Partly contradicting the traditional wisdom that market forces cause competitive salary differentials between occupations and sectors, our results suggest more differentiated levels in accordance with the scientific discipline of the doctoral subject in the business sector. Nevertheless when considering the statistical significance of these figures, disparities seem to be only significant in the higher education sector. Doctoral degrees awarded in the humanities are in general less remunerated in the labor market, which is why we took the humanities as reference level in our model. Compared with this reference group, PhD holders in the medical sciences and the social sciences earn a significant higher salary. We should remark that the high salaries of social sciences doctorate holders in our study are slightly biased by the fact that a rarefied group of these social scientists are in high-level positions with exceptionally high salaries.

Because of a significant influence of the scientific field on occupations held by PhD holders and significantly different pay scales between occupations, we might suppose an intervening effect of occupation on the relation between scientific field and salary. PhD holders in the natural sciences and engineering can be more often found in management positions, while PhD holders in the social sciences and the humanities are more often employed as legal, social and cultural professionals. Managers, in turn, earn significantly more than legal, social and cultural professionals.

Fifth, we assumed an impact resulting from the occupation in the organization and the salary earned. Several researchers managed to demonstrate the existence of a direct relationship between firm tenure, general labor market experience, and salaries (Altonji and Shakotko 1987; Abraham and Farber 1987; Topel 1991; Altonji and Williams 2005). These studies originally did not take into account occupation as a covariate. Kambourov and Manovskii (2009a, b) rejected these findings after having found that industry and firm tenure do not contribute to explaining the variation in salaries after controlling for occupation tenure. Sullivan

(2010) attempted to integrate both research outcomes in an upgraded analysis by also considering within-firm occupational mobility. This new element plays a significant role in determining the influence of industry and occupation-specific human capital on salaries. Briefly stated, the impact of industry and general work experience on salaries is dependent on the occupation in which one is employed. We did not insert an interaction effect between general labor experience and occupation in our models, so we are not able to draw statistical conclusions on the combined action of both factors. The interaction effect of industry sector and occupation is presented in significant differences in remuneration between universities and industry for several occupational groups, such as managers, science and engineering professionals, and business and administration professionals.

As a sixth element impacting on salaries, we consider the labor status in terms of contractual arrangements between PhD and his/her employer. A temporary contract can be a stepping stone to a permanent job. Nonetheless, workers with fixed-term contracts often have lower salaries and fewer benefits (e.g. health insurance and employer-provided pension plans) than workers with indeterminate labor contracts (Peck and Theodore 2000; Booth et al. 2002; Lane et al. 2003). Even after controlling for other possible dependent variables, such as lower educational attainment and fewer years of working experience, these differentials persist (Bentolila and Dolado 1994).

The proportion of doctorate holders with permanent contracts in industry (98 %) is very different from the percentage in higher education (56 %). It takes much more time to acquire a permanent position (a labor contract of indeterminate duration) in higher education than in industry. Furthermore, once a university employee manages to become permanently appointed, this change in labor position exerts a significant and strong effect on the size of the salary.

Finally, according to analyses carried out by Le Grand and Tåhlin (2002), job mobility entails significant salary increases. They approach internal and external mobility as two separate phenomena. Internal mobility is described as job changes within a firm, while external mobility is defined as the movement of workers between employers. Both types of mobility are negatively correlated, which may indicate that workers who move internally and workers moving between employers constitute different categories with dissimilar characteristics. Independent of the type of mobility, mobile employees can count on steeper earnings growth curves than stable workers. In particular, workers involved in internal movements especially, if sufficiently frequent, can benefit financially from these career turns. Internal mobility exerts its influence on salary level independent of advancements in occupational position. External mobility, on the other hand, affects salaries through its interacting with changes in the occupational situation.

Several studies (e.g. Topel and Ward 1992) have shown that job mobility by men has a significant influence on their salary growth. The evidence with regard to the impact of job mobility on women's salary growth is less elaborate and produces mixed results. During the first 10 years of labor market experience, job mobility accounts for up to 30 % of the total salary growth for men and only 8.3 % for women (Del Bono and Vuri 2011). We found no evidence of the impact of past job mobility on the salary scales of men and women.

Shin et al. (2010) find an inverted relation between job mobility and salary growth at the moment of the job hop. In their analyses, movers experience a greater initial salary loss than stayers. Yet this initial drop in income will be compensated in the years following the job movement. Compared to stayers, movers experience steeper salary increases a couple of years after the job change. The time needed to catch up with the negative impact of a job movement on salary is different for voluntary job changers than for those who had to change jobs involuntarily. To sum up, voluntary movers recover from the initial salary loss within 3 years, while involuntary movers need an extra 2 years to make up the pecuniary loss.

After having elaborated on the effects of job mobility on salaries we descend one level in the hierarchy of causes and consequences and focus our attention on the elements lying at the basis of job mobility. The probability that workers quit their job declines with labor-market experience and firm-specific mobility (Parsons 1977; Mincer and Jovanovic 1981). Farber (1994) discovered a significant effect of previous job mobility on future job movement. In addition, Baker et al. (1994) found that workers who receive larger salary increases early in their job experience less impediments to promotion. The factors which determine the job hopping behaviour of our sample of doctorate holders were not part of our research design. Further analyses could confirm or reject the presence of similar patterns as in the studies mentioned previously. Past mobility is of no importance to explain the salary distribution of doctorate holders, neither for industry nor for higher education.

6.2.3 Researchers and PhD Careers

The literature is quite limited regarding the elements that determine the choice for a research career. Notwithstanding the fact that doctorate holders are trained to conduct scientific research, a considerable share leaves a research career path and choices for other opportunities. This does not necessarily imply that the skills they have acquired while working on their doctorate become useless. 65 % of doctorate holders employed outside a university indicated that 10 years after their graduation, there was still a link between the content of their current job and the subject they explored during their doctorate (Boosten et al. 2014). In the hope to elucidate this matter, we constructed a second model synchronously with the first model in which we try to explain the elements that determine the choice for a career in scientific research.

First, we consider the different sectors of employment that might have a bearing on pursuing a research career. The decision to search for jobs in a specific sector of employment after graduation is not a randomly based career choice. In most cases, preferences and decisions made during the doctorate assert themselves the moment individuals enter the labor market. Mangematin (2000) points out how the contract between the PhD student and his supervisor determines the scientific work carried out during the doctoral trajectory. Students who prefer a career in the business sector collaborate more with companies, while students who want to work in academia have higher numbers of publications. Briefly stated, the way of doing the PhD affects the future sector of employment. Mobility between the first job after the PhD and a job some years later is very low. Roach and Sauermann (2010) describe how the preferences of doctoral students for a specific employment sector are linked to a series of personal attributes: students who prefer industrial employment show a weaker taste for science (i.e. a research career), a greater concern for salary and a stronger interest in downstream work compared to students who chose for an academic career.

Lee et al. (2010) cite several studies showing a declining importance of the academic sector for the employment of science and technology PhDs. Industry is gradually replacing academia as the top employment sector for doctorate holders in the domain of science and technology (e.g. Stephan 1996; Stephan et al. 2004).

Referring to our analyses, some factors differ between industry and higher education in their impact on the choice of doctorate holders for a research career. Salary, age and type of labor contract appear to have a significant effect on the pursuit of a research career in higher education but not in the business sector. Gender, on the other hand, plays a substantial role in the orientation of workers towards research jobs in industry. Each of the factors mentioned here contributes in a significantly different way to the probability of choosing a research career according to the sector of employment.

Second, the type of labor contract plays a determining role in the development of a research career. Robin and Cahuzac (2003) examined the effect of the contract a PhD holds after graduation in anticipation of a permanent position at a university. They distinguish between two types of labor contracts: a post-doc research position abroad or a fixed-term contract in the public or private sector at home (i.e. France). Both employment contracts have different effects on the likelihood of obtaining a tenure-track academic position. Although a post-doc research position delays the appointment to a permanent academic position, its effect on the probability of finding such a position is less negative compared to employment with a fixed-term contract. It is also worthwhile noting that a post-doc research position has a favourable effect on the likelihood of finding a permanent job in the private sector.

Collinson (2003) elaborates further on this theme by stating that the number of researchers employed at universities in temporary contracts has soared in recent decades. They refer to a study by Bryson and Barnes (2000) to draw a picture of the situation in the UK, where about 50 % of current academic staff are employed on fixed-term contracts. Few researchers manage to obtain a permanent research position in a university and those who succeed seem to dispose of specific characteristics. The absence of family responsibilities such as children and the payment of a mortgage, and the financial support of a partner with a permanent job make it more likely to persist in temporary contract research. Moreover, institutional features such as being employed in permanently established research centres or departments with a strong emphasis on research offer better opportunities for fixed-term researchers to stay on a research career track. Lee et al. (2010) notice the difficulties PhD graduates experience in their attempt to obtain a permanent contract in the academic sector. This is in contrast to the manufacturing sector which offers permanent positions within a short period after recruitment.

We found that doctorate holders with a permanent contract have a higher probability of being engaged in research activities at the university. Not having a contract of indeterminate duration lowers the access of university staff to research functions.

A third element is the occupation that impacts the research career. Lavoie and Finnie (1998) investigated the careers of engineers and concluded that a relatively high proportion of engineers are employed in non-engineering occupations. Among these non-engineering occupations, management has become an attractive occupation for engineers. This finding is nuanced by the fact that large parts of management jobs hold by engineers are related to the field of engineering. Engineers in management positions are perhaps no longer fully engaged in technical activities, but they nonetheless maintain links with the technical operations in the organization for which they work. Engineers employed in non-technical positions have the lowest salaries and report to be less satisfied with their job. Engineers moving from a job with a technical content to a management position earn more than their colleagues who move between technical occupations. Apparently, this change in occupation has no influence on satisfaction of reported earnings.

In the already mentioned study by Lee et al. (2010), the authors conclude that research positions in academia or manufacturing have become secondary occupations for PhD graduates in science and technology (S&T). Tenure-track careers in academia and research positions in R&D laboratories in industry are no longer a logical career continuation after completing a PhD. Possible alternative career opportunities encompass management and consultancy, software development in the services sector, and non-research positions in academia and public organizations.

Doctorate holders in the humanities and social sciences represent more than 90 % of the legal, social and cultural professions. These professions in general are not associated with a typical research career. For this reason, we took this professional group as a reference for our analyses on the influence of occupation type on the ambitions of doctorate holders to pursue a research career. Doctorate holders in engineering jobs are more likely to follow research career tracks than those in legal, social and cultural professions. All other occupations outside engineering appear not to differ from the legal, social and cultural professions in steering the careers of doctorate holders towards a research career.

Finally, we look at the impact of the scientific discipline of the PhD and its chances to pursue a research career. Lavoie et al. (2003) discern a growing trend towards knowledge work in Canada in the period 1971–1996. They make two remarkable observations in their study. First, the growth of knowledge work was supported by high growth rates in the number of ICT occupations, but it is striking to see how this evolution underwent a strong slow-down during the most recent period (1991–1996). Second, engineering and science occupations represent a small proportion of all employment defined as knowledge work and these groups play a minor role in explaining the growth of knowledge occupations. The group of occupations in social sciences and humanities, on the other hand, represents approximately 50 % of all knowledge employment and this group saw a much stronger growth rate than that of engineering and science occupations.

Since we used a more limited definition of knowledge work, it is difficult to draw parallels with the trends described by Lavoie et al. (2003). Nonetheless, we could not establish any kind of relation between the scientific field of the doctorate's subject and a research-based career. Based on our analyses we found no specific indications of an advantage from having written a doctorate in certain scientific disciplines such as engineering and natural sciences and the probability of choosing a researcher career. We only noticed a small comparative advantage of engineers compared to doctorate holders in the humanities. This could imply that research work is not necessarily reserved for doctorate holders in the field of natural sciences and engineering.

6.3 Dataset

The collection of the data is based on two databases. First, we used a database collected by the Flemish Ghent University. Second we utilized a database of the 'Conseil des Recteurs francophones' (the council of French-speaking chancellors). Both administrative databases register every person who has obtained a doctoral degree at a Dutch-speaking or a French-speaking university in Belgium respectively, starting from 1990. In the period 1990–1991 until 2008–2009, more than 24,500 researchers received a doctorate degree from a university in Belgium (14,404 in the Flemish Community and 10,137 in the French Community). To make sure both datasets contained the same cohorts (expressed per academic year), we confined our analyses to all individuals who obtained a doctoral degree in the period between January 1990 and December 2008.

To approach the respondents and to obtain their most recent addresses, we used the resources of the National Register. The National Register is a public service authorized to collect and store data with respect to the identity of Belgian citizens. A substantial number of the respondents could not be traced in the National Register, either because the national registration number was missing or the potential respondents had moved abroad. As a result, survey invitations were sent out by the National Register to only 16,911 potential respondents or 70.9 % of the survey population, but the characteristics of respondents included or excluded from the sample (discipline, gender, nationality) could not be provided. The National Register acted as a trusted third party in this process: respondents were able to take part in the on-line survey fully anonymously. 5,448 of these 16,911 potential respondents returned the survey (32.2 %). For analytical purposes, filters were used to eliminate returned questionnaires that were useless, resulting in a response rate of 28.3 % (4,778 respondents) in the majority of the questionnaire modules. All respondents with a foreign nationality (not Belgian) were removed from the sample. European citizens are not obliged to register in the community where they reside;

consequently, they are not registered by the National Register. Because of this lack of information it is not possible to establish a representative sample of all foreigners who obtained a doctoral degree at a Belgian university. In light of the models tested in this chapter, we removed an additional 2,272 persons from the dataset because they reported insufficient information for the relevant variables.

Comparing the composition of the sample of respondents with the population from the administrative university databases showed that both distributions were significantly different according to gender and scientific discipline. Only those two variables are available to us to draw conclusions about our sample's representativeness. Altogether this is not surprising since the older age cohort was less inclined to complete the questionnaire. Doctorate holders who graduated in the last 10 years were more motivated to report on their career developments. Furthermore, since the composition of the population of doctorate holders underwent a fundamental shift regarding gender and discipline, we expect this to be the main reason of our flawed test for an equal composition of sample and population. Women are overtaking men regarding the number of doctoral degrees awarded. The younger cohorts, in particular, show an increasing number of women starting a doctoral trajectory. The same can be said about the scientific field of the doctorate: natural scientists were traditionally overrepresented in the population of doctorate holders, while other disciplines (particularly medical sciences, engineering and social sciences) have evolved in recent years to the same level. This has changed the composition of the population. The combination of both factors, different response rates per age cohort and a modified structure of the underlying population, explain why our sample is not representative of the broader population.

6.4 Analysis

The descriptive statistics about the entire sample and the sub-samples per sector of employment are summarised in Table 6.1. Additionally, the main differences between the two sectors are calculated.

On average, gross salaries of PhDs in Belgium are 58,462 euros. As can be seen, on average the earnings are almost 12,000 euros higher in industry than in higher education, and this is a significant difference (at the 0.1 % level of significance). The majority of PhDs (77 %) are currently employed as a researcher and this is, as expected, significantly higher when employed in higher education (84 %) than in industry (69 %). Obtaining a PhD is, after all, a prerequisite in higher education to pursue an academic career. Since there is obviously no guarantee on getting such a position, many PhD holders are forced to leave the academic environment and work for industry (or government organizations). Almost two thirds (72 %) of PhDs are obtained by males.

The differences in employment sector are significant (at the 5 % level), and female PhDs are employed relatively more in higher education. Age and experience of PhD holders do not differ between higher education and industry. But when looking at the field of science (education) or function (occupation) of the PhD, they

Table 6.1 Descriptive statistics

	All respondents (N = 2016)	Higher education (N = 1057)	Industry (N = 959)	Difference between higher education and industry	Significance of difference
Salary (in € p. a.)	58,462.32	52,757.36	64,750.26	−11,992.9	****
Researcher (0/1)	0.77	0.84	0.69	0.15	****
Gender (0/1)	0.72	0.69	0.73	−0.05	**
Age (years)	37.6	37.7	37.6	0.10	
Experience (months)	97.6	99.0	96.1	2.90	
Education—natural sciences (0/1)	0.39	0.33	0.46	−0.13	****
Education—engineering (0/1)	0.23	0.18	0.28	−0.11	****
Education—medical sciences	0.12	0.14	0.10	0.03	**
Education—agricultural sciences (0/1)	0.10	0.09	0.11	−0.02	*
Education—social sciences (0/1)	0.10	0.16	0.03	0.13	****
Education—human sciences (0/1)	0.07	0.12	0.02	0.10	****
Occupation—manager (0/1)	0.14	0.01	0.28	−0.26	****
Occupation—engineer (0/1)	0.46	0.41	0.51	−0.10	****
Occupation—medical (0/1)	0.03	0.03	0.03	−0.00	
Occupation—education (0/1)	0.23	0.44	0.00	0.43	****
Occupation—economic (0/1)	0.03	0.01	0.06	−0.05	****
Occupation—ICT (0/1)	0.05	0.02	0.09	−0.07	****
Occupation—legal, social, cultural (0/1)	0.06	0.08	0.03	0.04	****

(continued)

Table 6.1 (continued)

	All respondents (N = 2016)	Higher education (N = 1057)	Industry (N = 959)	Difference between higher education and industry	Significance of difference
Permanent (0/1)	0.76	0.56	0.98	−0.41	****
Full-time (0/1)	0.92	0.90	0.95	−0.05	****
Past job mobility (0/1)	0.60	0.61	0.59	0.02	

Notes: The symbols ****, **, * refer to a significance level of 0.1, 1, 5 and 10 %. Differences are tested using t-tests for continuous variables and pr-tests for binary variables

are distributed differently. In the case of education, PhDs specialised in natural sciences and engineering are employed proportionally more in industry. PhDs in social sciences and humanities—even though they make up 17 % of the entire sample—are proportionally more active in higher education. PhDs in medical sciences are also employed relatively more in higher education. Overall, almost half (46 %) of PhDs are employed as engineers, followed by positions in education (23 %) and managers (14 %). The distribution of PhDs by occupation differs, as might be expected, between higher education and industry. Comparing industry to higher education, PhDs are proportionally more employed as managers, engineers and to a lesser extent, in ICT or an economic function. PhDs in higher education are, first and foremost, active in education when compared to those working in industry. The type of position is captured by looking at the status of the contract, temporary or permanent, and the duration of employment, part-time or full-time. About three quarters of PhDs (76 %) have a contract that is undetermined in time and one quarter has temporary employment. These shares are significantly (at the 0.1 % level) different for higher education, which is just above half the PhDs (56 %), when compared to industry (98 %). Most PhDs are in full-time employment. However, the difference between higher education and industry is still significant (at the 0.1 % level): PhDs in higher education work part-time more than PhDs in industry. Most PhDs (60 %) have experienced some past job mobility. Job mobility, however, does not differ between PhDs that are currently employed in higher education or industry.

In the remainder of the chapter we will examine the effects of key characteristics on the pecuniary gains (the 'gold') and the research career (the 'puzzle') when obtaining a PhD.

Table 6.2 looks at the effects of an array of characteristics of a PhD holder by sector of current employment and their impact on current salaries earned in 2009.

The discussion will be centred on the differences between higher education and industry. The first three columns (i–iii) check on the influence of personnel, educational, functional and contractual characteristics on the level of gross earnings i.e. salary. In the case of PhDs pursuing a career as a researcher, the results in

Table 6.2 PhD salaries in higher education and industry—regression analyses

	Higher education (i)	Industry (ii)	Difference in coefficients (iii)
Researcher	6947.2**** (6.35)	1321.8 (0.54)	5625.4*
Gender	3696.5**** (4.32)	8834.9**** (4.92)	−5138.4****
Age	710.1**** (7.18)	1863.6**** (8.41)	−1153.4****
Experience	17.9** (2.25)	68.1*** (3.12)	−50.2****
Education—natural sciences	999.0* (0.74)	2413.8 (0.16)	−1414.7*
Education—engineering	3036.6* (2.12)	3909.5 (0.26)	−872.9*
Education—medical sciences	3429.5** (2.23)	7263.5 (0.48)	−3834.0
Education—agricultural sciences	3080.9* (1.78)	5868.8 (0.38)	−2787.9
Education—social sciences	3489.1** (2.35)	6313.9 (0.43)	−2824.8
Occupation—manager	11907.1*** (2.62)	12128.4** (2.23)	−221.3***
Occupation—engineer	665.6 (0.43)	−4444.1 (−0.93)	5109.7***
Occupation—medical	8337.7* (1.88)	−4884.3 (−0.66)	13222.0
Occupation—education	−398.3 (−0.27)	−9126.9 (−1.37)	8728.6*
Occupation—economic	4784.6 (1.21)	5208.5 (0.91)	−423.9**
Occupation—ICT	−394.5 (−0.10)	−9672.5** (−1.98)	9277.9
Permanent	6209.7**** (6.72)	7790.9 (1.59)	−1581.1****
Full-time	−239.9 (−0.15)	382.7 (0.09)	−622.6****
Past job mobility	1090.2 (1.40)	−505.6 (−0.31)	1595.8****
Intercept	9160.7** (2.27)	−31071.6** (−2.10)	
No. of observations	1057	959	
R^2	34.2	31.0	
F	26.2****	23.4****	

Notes: The symbols ****, ***, **, * refer to a significance level of 0.1, 1, 5 and 10 %. Robust standard error is in brackets. The reference category for education is human sciences; for occupation, the reference category is when employed as a social, legal and cultural specialist

Table 6.2 demonstrate that a researcher with a PhD degree in higher education earns, on average, almost 7,000 euros more than a PhD holder who does not pursue a research career in that sector. In industry, a researcher earns over 1000 € (1,321.8 €) more than a PhD holder not in a research function. The difference, 5,625.4 euros, is only slightly significant (at the 10 % level).

Table 6.2 further shows that, on average, a male PhD earns more than female PhDs irrespective of the sector of employment. In higher education the salary gap between female and male PhDs is 3,700 euros in favour of the male PhDs. This salary gap is, at 8,800 euros, even higher in industry. The sector difference, 5,100 euros is highly significant: the salary gap in higher education is significantly smaller than that in industry. The fact that female PhDs in higher education earn less might have to do with several factors. First, the fact that female PhDs are only more recently employed in higher education although the popular press regularly highlights their smaller number. In addition, in our sample we found that there are more male than female PhDs (see Table 6.1 earlier). We tested this using age and experience differences between genders in both sectors. The t-test indicates that, in industry, the age of female PhDs is significantly (at the 5 % level) less than male PhDs (just over 1 year). In higher education the difference is about 1.7 years, significant at 0.1 %. Since female PhDs are younger this might, therefore, explain why they earn less than male PhDs. These findings are corroborated when experience is brought in: in both industry and higher education, the female PhDs are less experienced than male PhDs (at a significance level of 0.1 %). Second, female PhDs might opt proportionately more for part-time work. The t-tests, however, do not provide any empirical ground for this assertion. Third, the function performed by PhDs might also play a role. T-tests show that female PhDs are significantly (at 0.1 %) less occupied as a researcher in industry, and the same applies to higher education (at the 1 % significance level).

Again, in both sectors age has a significant impact on the salary level. Yet, an additional year in industry brings significantly higher salaries compared to in the higher education sector. The same observations hold for the impact of monthly experience.

When focused on educational discipline, the field of science in which the PhD has been obtained does not matter. In the case of the regressions, the reference category is a PhD in human sciences. Although more is earned when employed in industry, none of the other disciplines compared to human sciences exerts a significantly more positive impact on the salary level. This is not the case where the higher education sector is concerned. Obtaining a PhD in engineering, medical sciences, and social sciences results in a higher level of salary, when compared to a PhD in human sciences.

In the case of occupation, PhDs employed as a manager earn much more than PhDs working as social, legal or cultural specialists—this is the case in both higher education and industry. The difference between both these sectors is, although small, still highly significant (at the 1 % level of significance). A similar finding is recorded for PhDs working as economists or administrative specialists. PhDs working in ICT and education, on the other hand, are making less money than those working as social, legal or cultural specialists. However, even though they earn much less in industry, the difference with higher education is non-existent (ICT) or weak (education).

Having a permanent employment position positively impacts the size of the salary: in industry the salary in this case is almost 8,000 euros (7790.9), and over 6,000 euros in higher education (6209.7). This impact, however, is only highly significant (at the 0.1 % level) in the case of higher education. The difference between the two sectors is also very significant (0.1 % level). We consider this issue in detail by performing t-tests and pr-tests, and by investigating if a permanent position is associated with pursuing a research career, age, gender, and past job mobility. The findings indicate that, for industry, there is a weak effect (at the 10 % significance level) for female PhDs who have relatively more temporary contracts. Where higher education is concerned, we see many significant differences. First, temporary contracts are more for younger PhDs (34.2 years on average; whereas 40.3 years is the average for permanent contracts (at 0.1 % significance). Next, significantly (at 1 %) more females have temporary contracts than males (35.4 % versus 26.9 %). Third, people with research careers have proportionally less permanent contracts (at 0.1 % of significance). Finally, past job mobility is significantly (at the 1 % level) associated with having a permanent contract: of the PhDs in higher education that temporarily were employed, 55.7 % have had some past job mobility; whereas this share was 65.7 % for PhDs in higher education with permanent contracts.

Table 6.3 looks at the potential different impacts of some key variables on the option to pursue a research career when employed in higher education or industry.

The coefficients of the probit regression say something about the effects of independent variables on the probability of pursuing a career as researcher in both higher education (column i) and industry (column ii). Column (iii) looks at the sector difference of these estimated coefficients (Table 6.3). First let us consider the impact on a research career in higher education. Even though the motive to become a researcher is an ‘intrinsic’ one depending on personal aspiration, the salary also exerts a significant impact on the choice. The variable gender is positive and slightly significant, implying that female PhDs are still a bit more anxious to become a researcher. This might be due to aspirations, or other reasons. Male PhDs are perhaps less involved in raising a family, for example. Age is negatively related to research careers: the older the PhDs working at universities get, the more they take on non-research positions. Where education is concerned, only the PhDs in engineering are significantly (although only at the 10 % level) more interested in research careers than PhDs in human sciences. In the case of occupation, the PhDs acting as managers are significantly less (again at only 10 % significance level) interested in a research career than PhDs active as specialists in social, legal or cultural matters. The PhDs working as science and engineering professionals are, on the other hand, significantly (at 1 %) more interested than professionals in social, legal and cultural sciences in aiming for a research career. The negative association between a permanent contract and a research career in higher education is consistent with earlier findings reported in the pr-tests in Table 6.2. Researchers have

Table 6.3 PhD research careers in higher education and industry—probit regression analyses

	Researcher—probit regressions			Marginal effects after probit	
	Higher education (i)	Industry (ii)	Difference in coefficients (iii)	Higher education—dy/dx (iv)	Industry—dy/dx (v)
Salary	0.00**** (5.03)	0.00 (0.44)	0.00****	5.41e-06**** (5.30)	2.84e-07 (0.44)
Gender	0.20* (1.82)	0.57**** (5.57)	−0.37***	0.043* (1.75)	0.210**** (5.42)
Age	−0.03*** (−3.19)	0.00 (−0.36)	−0.03****	−0.007**** (−3.22)	−0.001 (−0.36)
Experience	0.00 (−1.15)	0.00 (0.02)	0.00****	−0.000 (−1.15)	8.02e-06 (0.02)
Education—natural sciences	−0.02 (−0.13)	0.09 (0.25)	−0.11	−0.005 (−0.13)	0.031 (0.25)
Education—engineering	0.35* (1.83)	0.06 (0.17)	0.29***	0.063** (2.09)	0.021 (0.17)
Education—medical sciences	0.20 (0.97)	0.31 (0.82)	−0.11*	0.037 (1.07)	0.100 (0.89)
Education—agricultural sciences	0.12 (0.52)	−0.07 (−0.20)	0.19**	0.023 (0.55)	−0.026 (−0.20)
Education—social sciences	0.29 (1.63)	−0.01 (−0.03)	0.30*	0.053* (1.83)	−0.004 (−0.03)
Occupation—manager	−0.66* (−1.68)	0.29 (1.17)	−0.95	−0.186 (−1.35)	0.097 (1.22)
Occupation—engineer	0.66*** (3.20)	0.68*** (2.79)	−0.02****	0.128**** (3.42)	0.235*** (2.87)
Occupation—medical	0.08 (0.23)	−0.01 (−0.04)	0.09**	0.016 (0.24)	−0.004 (−0.04)
Occupation—education	0.04 (0.22)	−0.20 (−0.21)	0.24	0.008 (0.22)	−0.072 (−020)
Occupation—economic	−0.39 (−1.00)	−0.03 (−0.11)	−0.36	−0.098 (−0.85)	−0.011 (−0.11)
Occupation—ICT	−0.18 (−0.47)	0.03 (0.10)	−0.21	−0.041 (−0.43)	0.010 (0.11)
Permanent	−0.30** (2.55)	−0.38 (−1.20)	0.07****	−0.0061*** (−2.59)	−0.117 (−1.38)
Full-time	−0.35** (−2.05)	0.08 (0.37)	−0.43****	−0.060** (−2.43)	0.030 (0.37)
Past job mobility	0.18* (1.76)	−0.06 (−0.64)	0.24****	0.039* (1.73)	−0.020 (−0.64)
Intercept	0.88** (2.07)	0.01 (0.01)			
No. of observations	1057	959			

(continued)

Table 6.3 (continued)

	Researcher—probit regressions			Marginal effects after probit	
	Higher education (i)	Industry (ii)	Difference in coefficients (iii)	Higher education—dy/dx (iv)	Industry—dy/dx (v)
McFaddens R^2	13.6	6.5			
Wald chi^2	107.0****	76.4****			

Notes: The symbols ****, ***, **, * refer to a significance level of 0.1, 1, 5 and 10 %. Robust standard error is in brackets. The reference category for education is human sciences and for occupation it is when employed as a social, legal and cultural specialist

significantly (at the 5 % level) less permanent contracts than non-researchers. The same applies to a full-time position: researchers often have part-time contracts. Finally, there is a weak significance (at the 10 % level) between past job mobility and a researcher. It might be that a researcher has had several jobs because job positions as researcher at higher education institutes are scarce.

The results in the industry sector are less clear-cut. Salary plays a non-significant role in pursuing a research career. The difference with higher education is, however, positive, implying that the effect of salary is significantly stronger in higher education than in industry. In the case of gender, female PhDs are significantly (at the 0.1 % level) more anxious to become a researcher in industry than male PhDs, making the difference between the sectors significantly higher in industry. Age is non-significant, as is experience. Experience, however—when considered in terms of sector differences—is significantly more important (at the 0.1 % level) in higher education than in industry. Each field of science is equally important in choosing to become a researcher in industry since there are no significant effects when compared to the reference category. However, being a trained scientist and engineer has a significantly greater impact (at the 1 % level) on becoming a researcher in higher education than in industry. Those employed as a engineer, are, in higher education, significantly more interested in a research career than professionals in social, legal and cultural sciences. Yet, the sector difference of these effects is significantly higher (at the 0.1 % level) in industry than in higher education. The next three variables on the type of contract (whether permanent or temporary, and full or part-time) and past job mobility show no impact on the probability of becoming a researcher in industry. However, the positive difference in the case of permanent contracts shows that although the temporary contracts are associated with researchers, the effect is clearer in higher education. Past job mobility, apparently, is also more standard in higher education than in industry. This might be related to the fact that job openings as researchers at universities are more scare than in industry leading to significantly (at the 0.1 % level) more 'job hopping' behaviour.

The marginal effects after probit regressions help to interpret the estimated coefficients (columns iv and v, Table 6.3). The predicted probability of working in higher education is 87 % for a researcher when all other variables are taken at their mean values. A one euro increase in salary raises the probability to be a researcher by a very small percentage. A male PhD is 4.3 % more likely to become a researcher in higher education than female PhDs. Each year a PhD holder ages reduces his or her likelihood of becoming a researcher in higher education by 0.7 %. A PhD in science and engineering increases the probability of becoming a researcher by 6.3 %. When the PhD works as a professional engineer, he/she increases the probability of becoming a researcher by 12.8 %. Having a permanent contract, on the other hand, reduces the likelihood of becoming a researcher by 0.6 %; whereas working full-time reduces this likelihood by 6 %. In industry, the predicted probability of being a researcher is 70 %. For the rest, not many effects are discerned. When a PhD is a scientist or engineer in industry, the probability of working as a researcher augments by 23.5 %.

6.5 Conclusions

This chapter focussed on two motives driving the pursuit of a PhD career: the salary earned by the PhD and functioning as a researcher for which the PhD was trained. From the start of the chapter, we looked at two distinct sectors of employment: higher education and industry. In higher education, obtaining a PhD is a prerequisite to a career. In industry, having a PhD offers research skills that are valuable individual assets. This is the rationale for our exploratory efforts investigating whether or not there are major sector differences.

Many sector differences are identified. First, PhDs in higher education earn less than PhDs employed by industry. Furthermore, higher education employs a higher share of researchers with a PhD and a higher share of female PhDs. However, PhDs in higher education have far more temporary labor contracts. PhDs in higher education are relatively less trained in natural sciences and engineering than in industry, but more trained in social sciences and humanities compared to in industry.

Looking at the impacts on salary, sector differences appear again. A research career in higher education has a significant effect on salary which appears to not be the case in industry. The same finding applies to the type of labor contract: having an indeterminate contract in higher education—which is the case for just over half the respondents—has a positive impact on salary. The functioning of the labor market, therefore, fundamentally differs for both sectors and this should be acknowledged at a policy level.

Research contributes to the building of a knowledge-based economy. Tacit knowledge is embodied in highly skilled people such as those with PhDs. Thus policies should target PhDs to help them become researchers in both higher education and industry. Our findings suggest that research careers in higher education and industry differ in certain aspects. First, male PhDs are far more active as researchers in industry, whereas there is more gender equality in higher education concerning research functions. In higher education, older PhDs are less inclined to remain in a research capacity. Other differences are found in the labor contract: PhDs with an indeterminate contract are less inclined to do research activities; and the same applies to PhDs that become full-time employees. This might reflect the temporality of taking part in the competitive culture of publishing articles (‘publish or perish’) which too often serves as a threshold to become a full professor.

These findings are in line with results obtained by other authors cited in this chapter. The explorative nature of our approach may be a starting point for further investigation on the turning points in the careers of doctorate holders. The fact that career choices in industry and higher education are explained by a diverse range of factors could be indicative of underlying preferences and decisions. A central topic in future research is the study of mutually advantageous spillover effects of academic knowledge to firms, and of business practices to universities as exemplified by numerous articles on this subject. Since a significant group of doctorate holders moves from academia to the private business sector, this should leave somewhere significant trails along the development of doctorate holders’ careers.

References

Abraham K, Farber H (1987) Job duration, seniority, and earnings. Am Econ Rev 77(3):278–297

Altonji JG, Shakotko RA (1987) Do wages rise with job seniority? Rev Econ Stud 54(3):437–459

Altonji JG, Williams N (2005) Do wages rise with job seniority? A reassessment. Ind Labor Relat Rev 58(3):370–397

Antonczyk D, Fitzenberger B, Sommerfeld K (2010) Rising wage inequality, the decline of collective bargaining, and the gender wage gap. Labour Econ 17(5):835–847

Arulampalam W, Booth AL, Bryan ML (2007) Is there a glass ceiling over Europe? Exploring the gender pay gap across the wages distribution. Ind Labor Relat Rev 60(2):163–186

Auriol L, Schaaper M, Felix B (2012) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators, 3rd edn. OECD Science, Technology and Industry working papers 2012/07. OECD Publishing, Paris. doi:10.1787/5k4dnq2h4n5c-en

Baker GP, Gibbs M, Holmstrom B (1994) The wage policy of the firm. Q J Econ 109(4):921–955

Barron JM, Black DA, Loewenstein MA (1993) Gender differences in training, capital, and wages. J Hum Resour 28(2):343–364

Bentolila S, Dolado JJ (1994) Labor flexibility and wages: lessons from Spain. Econ Policy 9 (18):53–99

Blau FD, Kahn LM (1996) Wage structure and gender earnings differentials: an international comparison. Economica 63(250):23–62

Blau FD, Kahn LM (1997) Swimming upstream: trends in the gender wage differential in the 1980s. J Labor Econ 15(1):1–42

Blau FD, Kahn LM (2000) Gender differences in pay. J Econ Perspect 14(4):75–99

Boardman PC, Ponomariov BL (2009) University researchers working with private companies. Technovation 29(2):142–153

Boosten K, Vandevelde K, Derycke H, te Kaat A, Van Rossem R (2014) Careers of doctorate holders survey 2010. R&D and innovation in Belgium, research series 13. Belgian Science Policy Office, Brussels

Booth A, Francesconi M, Frank J (2002) Temporary jobs: stepping stones or dead ends? Econ J 112(480):189–213

Bozeman B, Gaughan M (2007) Impacts of grants and contracts on academic researchers’ interactions with industry. Res Policy 36(5):694–707

Bryson C, Barnes N (2000) The casualisation of employment in United Kingdom higher education. In: Tight M (ed) Academic work and life: what it is to be an academic, and how this is changing. JAI, Amsterdam
Collinson JA (2003) Working at a marginal ‘career’: the case of UK social science contract researchers. Sociol Rev 51(3):405–422
Corcoran ME (1979) Work experience, labor force withdrawals, and women’s wages: empirical results using the 1976 panel of income dynamics. In: Lloyd CB, Andrews ES, Gilroy CL (eds) Women in the labour market. Columbia University Press, New York, pp 216–245
Corcoran ME, Duncan GJ (1979) Work history, labor force attachment, and earnings differences between the races and sexes. J Hum Resour 14(1):3–20
Coupé T (2003) Science is golden: academic R&D and university patents. J Technol Transfer 28 (1):31–46
D’Este P, Patel P (2007) University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry? Res Policy 36(9):1295–1313
Del Bono E, Vuri D (2011) Job mobility and the gender wage gap in Italy. Labour Econ 18 (1):130–142
Dietz JS, Bozeman B (2005) Academic careers, patents, and productivity: industry experience as scientific and technical human capital. Res Policy 34(3):349–367
Donohue JJ (1988) Determinants of job turnover of young men and women in the United States: a hazard rate analysis. In: Schultz TP (ed) Research in population economics, vol 6. JAI, Greenwich, CT, pp 257–301
Enders J (2002) Serving many masters: the PhD on the labour market, the everlasting need of inequality, and the premature death of Humboldt. High Educ 44(3–4):493–517
Farber HS (1994) The analysis of interfirm worker mobility. J Labor Econ 12(4):554–593
Felfe C (2012) The motherhood wage gap: what about job amenities? Labour Econ 19(1):59–67
Fox MF, Stephan PE (2001) Careers of young scientists: preferences, prospects and realities by gender and field. Soc Stud Sci 31(1):109–122
Friedman J, Silberman J (2003) University technology transfer: do incentives, management, and location matter? J Technol Transfer 28(1):17–30
Geuna A, Nesta LJJ (2006) University patenting and its effects on academic research: the emerging European evidence. Res Policy 35(6):790–807
Gronau R (1988) Sex-related wage differentials and women’s interrupted labor careers—the chicken or the egg. J Labor Econ 6(3):277–301
Herrera L, Muñoz-Doyague MF, Nieto M (2010) Mobility of public researchers, scientific knowledge transfer, and the firm’s innovation process. J Bus Res 63(5):510–518
Kambourov G, Manovskii I (2009a) Occupational specificity of human capital. Int Econ Rev 50 (1):63–115
Kambourov G, Manovskii I (2009b) Occupational mobility and wage inequality. Rev Econ Stud 76(2):731–759
Keith K, McWilliams A (1995) The wage effects of cumulative job mobility. Ind Labor Relat Rev 49(1):121–137
Lam A (2011) What motivates academic scientists to engage in research commercialization: ‘gold’, ‘ribbon’ or ‘puzzle’? Res Policy 40(10):1354–1368
Lane J, Mikelson KS, Sharkey PT, Wissoker DA (2003) Pathways to work for low income workers: the effect of work in the temporary help industry. J Policy Anal Manag 22(4):581–598
Lavoie M, Finnie R (1998) The occupational dynamics of recent Canadian engineering graduates inside and outside the bounds of technology. Res Policy 27(2):143–158
Lavoie M, Roy R, Therrien P (2003) A growing trend toward knowledge work in Canada. Res Policy 32(5):827–844
Le Grand C, Tåhlin M (2002) Job mobility and earnings growth. Eur Sociol Rev 18(4):381–400
Lee H, Miozzo M, Laredo P (2010) Career patterns and competences of PhDs in science and engineering in the knowledge economy: the case of graduates from a UK research-based university. Res Policy 39(7):869–881

Mangematin V (2000) PhD job market: professional trajectories and incentives during the PhD. Res Policy 29(6):741–756
Mansfield E, Lee JY (1996) The modern university: contributor to industrial innovation and recipient of industrial R&D support. Res Policy 25(7):1047–1058
Mincer J, Jovanovic B (1981) Labor mobility and wages. In: Rosen S (ed) Studies in labor markets. University of Chicago Press, Chicago, pp 21–63
Mincer J, Polachek S (1974) Family investments in human capital: earnings of women. J Polit Econ 82(2):76–108
Møen J (2005) Is mobility of technical personnel a source of R&D spillovers? J Labour Econ 23 (1):81–114
Munasinghe L, Reif T, Henriques A (2008) Gender gap in wage returns to job tenure and experience. Labour Econ 15(6):1296–1316
Parsons (1977) Models of labor market turnover: a theoretical and empirical survey. In: Ehrenberg RG (ed) Research in labor economics, vol 1. JAI Press, Greenwich, CT, pp 185–223
Peck JA, Theodore N (2000) Commentary: 'work first': workfare and the regulation of contingent labour markets. Camb J Econ 24(1):119–138
Perkmann M, King Z, Pavelin S (2011) Engaging excellence? Effects of faculty quality on university engagement with industry. Res Policy 40(4):539–552
Roach M, Sauermann H (2010) A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry. Res Policy 39(3):422–434
Robin S, Cahuzac E (2003) Knocking on academia's doors: an inquiry into the early careers of doctors in life science. Labour 17(1):1–23
Royalty AB (1993) Does job matching differ by sex? Yale Economic Growth Center working paper no. 689, New Haven
Royalty AB (1998) Job-to-job and job-to-nonemployment turnover by gender and education level. J Labour Econ 16(2):392–433
Schartinger D, Schibany A, Gassler H (2001) Interactive relations between university and firms: empirical evidence for Austria. J Technol Transfer 26(3):255–268
Shin D, Shin K, Park S (2010) Are initial wage losses of intersectoral movers compensated for by their subsequent wage gains? Macroecon Dyn 14(4):501–526
Siegel DS, Waldman D, Link AN (2003) Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory research. Res Policy 32 (1):27–48
Stephan PE (1996) The economics of science. J Econ Lit 34(3):1199–1235
Stephan PE, Sumell AJ, Black GC, Adams JD (2004) Doctoral education and economic development: the flow of new PhDs to industry. Econ Dev Q 18(2):151–167
Sullivan P (2010) Empirical evidence on occupation and industry specific human capital. Labour Econ 17(3):567–580
Topel RH (1991) Specific capital, mobility, and wages: wages rise with job seniority. J Polit Econ 99(1):145–176
Topel RH, Ward M (1992) Job mobility and the careers of young men. Q J Econ 107(2):439–479
Tornquist KM, Kallsen LA (1994) Out of the ivory tower: characteristics of institutions meeting the research needs of industry. J High Educ 65(5):523–539
Van Looy B, Ranga M, Callaert J, Debackere K, Zimmermann E (2004) Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? Res Policy 33(3):425–441
Waldfogel J (1997) The effect of children on women's wages. Am Sociol Rev 62(2):209–217
Williams N (2009) Seniority, experience, and wages in the UK. Labour Econ 16(3):272–283
Zucker LG, Darby MR, Torero M (2002) Labor mobility from academe to commerce. J Labour Econ 20(3):629–660

7 Professional Careers and Mobility of Russian Doctorate Holders

Natalia Shmatko and Yurij Katchanov

7.1 Introduction

The international mobility of skilled personnel, doctorate holders in particular, is the subject of much European research (Auriol 2007, 2010; Jonkers 2008; Musselin 2005). Usually, social shifts themselves are deemphasized in the studies, while the labor market structure (Altbach 1996; D'Agostino et al. 2009; Dhondt-Peltrault 2010; Fox and Mohaparta 2007) or the institutional peculiarities of scientific communities are emphasized (Jonkers and Tijssen 2008; Knight 1995; Saito et al. 2008). But it should be pointed out that mobility is a complex phenomenon which is not limited to a simple relocation from one country or organization to another but it is accompanied by a range of social causes and consequences. First of all, mobility is related to the changes of an individual's position in a social space, to the rises or falls of social status or "value", especially in the labor market. The view of "mobility" as of a "social process" along with a "physical relocation" implies the study of an individual's positional changes in the social hierarchy and of an individual's ability to mobilize various resources. In particular, it is a matter of the diversity of professional practices, for instance, a combination of research activity, teaching and consulting; simultaneous or consecutive employment in different sectors of economic activity; participation in different kinds of international cooperation, etc.

The analysis of a scientific community's social structure and of its core aspects, such as mobility and changes in social status, has always been one of the major issues for the sociology of science. However, attention has been usually paid to the knowledge economy rather than the structural analysis of social shifts. Russian sociologists and statisticians tend to concentrate on such problems as changes in the professional employment structure of R&D personnel (Gokhberg et al. 2010), the

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training of research personnel (Sivak and Yudkevich 2009), a study of secondary employment and project portfolios (Kulakova and Roshchina 2010) or the description of career trajectories of doctorate holders (Kachanov and Shmatko 2011; Suslov 2010).

Professional career can be described as the result of a multitude of acts of social mobility. Therefore, we can not study the researchers' career, without considering their mobility. The purpose of this study is to detect the main effects of social mobility of advanced degrees holders and to determine the impact of mobility on the development of researcher careers.

7.2 Social Mobility and Scientific Capital

The term "social mobility" in the paper denotes the transition of the doctorates from one position to another in academic space (cf. Sorokin 1927; Lipset and Bendix 1992). Generally, this space represents a network or structured system of socially defined positions. Academic space "is constructed in such a way that the closer" doctorate holders "which are situated within this space, the more common properties they have; and the more distant, the fewer" (Bourdieu 1989, p. 16).

Social mobility means the movement of doctorates from initial to final positions either higher or lower in academic space. Social mobility is integral to the continuity and change of academic space over time. With the same oversimplification, we can say that the analysis of their social mobility is the study of social shifts in academic space. The social mobility of advanced degrees holders can be attributed to the structural changes in the Russian academic space brought about by political and economic volatility which has promoted significant social shifts. Since social mobility estimates science-sustaining and academia-sustaining core transformations, answers to fundamental questions about social features, horizons, and opportunities of science and academia depend on the correct specification of that mobility. There are many indicators of scientific capital, and of social mobility. Surveys of these areas have been given by Pierre Bourdieu (1984), Seymour Martin Lipset (1959), John Goldthorpe (1987) and more recently by Mick Matthys (2012), among others. Social mobility and scientific capital are core characteristics of the academic space, and hence it is reasonable to enquire whether system of indicators of scientific capital can be used to elaborate in some way a related system of indicators of social mobility. That is one of tasks of the present paper.

At the same time, we can not operationalize mobility of doctorate holders until describing the academic space in which it is implemented. From a sociological viewpoint, the production of modern scientific knowledge occurs in a space of "forces, struggles, and relationships that is defined at every moment by the relations of power among the protagonists" (Bourdieu 1991, p. 3). The structure of this type of academic space or, what amounts to the same, space of relationships is characterized *grosso modo* by the distribution of scientific capital between the agents and institutions that operate in academic space (Bourdieu 1997, p. 14–21). Bourdieu's conceptualization of capital is related to "the set of actually usable resources and powers" (Bourdieu 1984, p. 114). In general, scientific capital may be defined as "accumulated labor… which, when appropriated on a private, i.e. exclusive, basis by agents or groups of agents, enables them to appropriate social energy in the form of reified or living labor" (Bourdieu 2002, p. 280). Roughly speaking, the concept of scientific capital highlights the process of accumulating specific resources and benefiting from the academic and administrative status that result in both reputational and power effects. Theoretically, social regularities of the knowledge generation are produced and reproduced through the distribution of scientific capital and the interests of the individual and collective agents in academic space (cf. Bourdieu 1985, p. 724–725). Scientific capital is an invariante property in academic space that is connected to the allocation of specific scientific power and recognition. Scientific capital takes its form and content from academic space within which it is used. Scientific capital is country-specific and its currency varies across different national social spaces. According to Bourdieu, scientific capital is a configuration of active properties (active in the sense that the properties represent a space of forces) that provide the agent with authority, recognition, influence, and power in a given academic space (Bourdieu 2004, p. 55–58).

Bourdieu's approach to scientific capital has been used and empirically tested (Bourdieu 1988; Brosnan 2011; Garforth and Kerr 2011; Hong 2008; Lebaron 2001; Panofsky 2011; Ruget 2002). For various critical analyses of this approach, see Bellotti (2011), Brubaker (2005), Calhoun (1993), Camic (2011), Coradini (2010), Grossetti (1986), Jain (2013), Lebaron (2003), and Sismondo (2011). In the literature, scientific capital is also presented (Bozeman et al. 2001; Bozeman and Corley 2004; Corolleur et al. 2004; Dietz and Bozeman 2005) as the sum of knowledge and work-relevant skills, social links, and resources. However, Bourdieu's version of the academic space—which has an integral character and strives to eliminate the contradictions between micro- and macro-sociological analysis, agents, and structures—seems preferable.

Bourdieu's concept of scientific capital exhibits three principal characteristics.

1. Scientific capital expresses the emergent quality of the set of an agent's active properties. The doctorate's scientific capital is examined as an attribute of unified academic space.
2. Understanding scientific capital as an integral configuration of active properties is tantamount to rejecting single-variant analysis based on "linear thinking, which only recognizes the simple ordinal structures of direct determination, and endeavors to reconstruct the networks of interrelated relationships which are present in each of the factors" (Bourdieu 1984, p. 107). Scientific capital is a system of active properties in which each quality strengthens the others.
3. The active properties are the efficient characteristics "that are selected as principles of construction" of the academic space; "are the different kinds" of scientific capital (Bourdieu 1985, p. 724).

Active properties can be interpreted as socially significant resources in the production of scientific knowledge. Here, we refer to resources that regularly result in a specific gain, a stake in the social game bounded by academic space, and that endure for a long period. In this type of interpretation, scientific capital determines the chances of an agent's attaining recognition or an administrative post. From this perspective, maximizing scientific capital can serve as the central problem of academic space. Maximizing scientific capital is naturally reflected in the variational principle [for an extensive discussion, the reader is referred to Katchanov and Shmatko (2014)], which governs the selection of the actual value of the active properties among all possible values for a given doctorate holder.

The variational principle postulates that under "quasi-steady-state conditions", among all the possible configurations of active properties, the observed configuration maximizes scientific capital (Katchanov and Shmatko 2014). In this case, it should be borne in mind that each agent may have his or her own variational principle, whose applicability is limited by his or her position in the academic space and his or her social trajectory. Thus, the agent's active properties attain a configuration that corresponds to the maximum scientific capital allowable for his or her scientific position and social trajectory. By identifying scientific capital with the quantity maximized by the true configurations of a doctorate's active properties, we introduce scientific capital as "a force inscribed in the objectivity of things so that everything is not equally possible or impossible" (Bourdieu 2002, p. 280).

Typically, scientific capital is maximized not as a result of rational planning but post factum. The variational principle does not require rational behavior from the agent (Kroneberg and Kalter 2012; Sen 1977). Maximizing scientific capital is the result of the determinations of social structures (Bourdieu and Wacquant 1992) and of the practical character of the PhD's actions (Heckathorn 1997).

The subjective mechanism that enables this variational principle is based on the idea of habitus, which includes routines and generates strategies. Habitus is a subjective social structure that can be interpreted as a system of durable, transposable dispositions that generate practices (Bourdieu 1992, p. 52–55). Habitus enables the socialized agent to spontaneously orient himself or herself in academic space and to act more or less relevantly without basing his or her behavior on explicit rules or reflexive models of behavior [for details, see Lenoir (2006) and Wacquant (2011)]. We proceed from the assumption that the PhD's behavior within academic space need not be rational but that his or her sociological explanation should be rational, which is precisely the principle of maximizing scientific capital. The maximum that constitutes the doctorate's scientific capital occurs in the process of deploying a self-learning, adaptive search strategy. This strategy is not based on conscious, rational calculation à la Max Weber. The principle is a goal of each local strategy. The latter is realized as a specific orientation of practice and is conditioned by the agent's habitus (Bourdieu 1992, p. 15–16, 62, 109). The doctorate holder's strategy selects high-yield combinations of the values of active properties. Each strategy seeks to reach a balance of efficiency and the stability of the agent's social trajectory within academic space: that is, to obtain the best results in different undefined social situations.

7.3 Methodology

The analysis of the mobility of Russian doctorate holders presented in the chapter is based on the data of dedicated survey "The Monitoring of the Labor Market for Highly Qualified R&D Personnel" conducted by the HSE Institute for Statistical Studies and Economics of Knowledge (ISSEK). Being a part of the international project "Careers of Doctorate Holders" (CDH) (Auriol 2007, 2010; Auriol et al. 2013) the Russian dedicated panel survey aims at monitoring of professional shifts and achievements of advanced degrees holders. Russia took part at two rounds of general data collection for the CDH survey: firstly in 2010 (year of reference—2009) and secondly in 2013 (year of reference—2012). The questionnaire and the sample were about the same in 2010 and in 2013, that enables us to track certain trends regarding development of Russian doctorate holders.

The target population included persons aged from 25 to 69 years who live and work in Russia and have doctoral degrees. In this panel survey, multistep stratified sampling was used with quotas under the following parameters: gender, age, field of science, employment sector and geographical area. The nationally representative sample was clustered within eight Russian Federal districts and stratified by the number of PhD graduates in each district. The sample of 3,450 persons in 2010 and 3,492 in 2013 was comprised of 54.8 % men and 45.2 % women who were employed at research institutes, universities and business entreprises and represented all fields of science and engineering: natural sciences (30.6 % respondents), engineering (18.5 %), medical sciences (11.2 %), agricultural sciences (4.0 %), social sciences (21.2 %) and humanities (14.5 %). Individual on-the-job interviewing was used.

General population of Russian doctorate holders (persons with an advanced research qualification, in possession of an ISCED 1997 level 6 degree), according to official statistics collected in the framework of the labor forces survey,[1] in 2012 comprised 88.5 % members of the labor force; among doctorates, 86.4 % were employed and 11.5 %—not employed and inactive and 2.1 %—unemployed. For comparison, in 2009, general population of doctorate holders was including 83.2 % members of the labor force; 80.1 % of them were employed, 16.8 %—not employed. It should be noted that during the period from 2009 to 2012, the proportion of employed doctorates increased by 5.3 %, while the unemployment rate decreased from 3.1 to 2.1 %. Most of them have a job in the fields of education, science and health.

In our analysis of careers and mobility of Russian doctorate holders we utilize 35 variables to estimate scientific capital of the respondents (for full set of variables, see Appendix 1). Using the indicators that Bourdieu employed in his investigation of the French academic space (Bourdieu 1988), these 35 variables can be sorted into the following three categories:

[1] Russian Federal State Statistic Service. Labor Statistics 2013: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/en/figures/labour/

1. "Symbolic power"—the active properties that provide the respondent with the ability to apportion other signs of scientific recognition (e.g., the respondent's number of peer-reviewed articles and monographs in leading journals, translations of his or her work into foreign languages, patents, scientific and academic awards from Russia and other countries, and grants received).
2. "Bureaucratic power"—the active properties that allow the respondent access to institutional resources (e.g., participation in scientific councils or editorial boards, membership on teams of experts, assignment to administrative posts connected with the distribution of employment and financial resources and with management of national and international scientific and educational projects).
3. "Academic power"—the active properties that enable control of the social reproduction of the corps of scientists (e.g., membership in professional organizations and associations, positions at universities, the supervision of dissertations).

The social mobility can be interpreted as the total "income" earned from scientific capital. The social mobility is a sophisticated phenomenon that is not limited to a set of activity properties but is related to that set by a range of social causes and consequences. The social mobility is linked to an individual's position within the scientific, academic and administrative hierarchy. The view of the social mobility as "a scientific gain" implies the study of diverse professional practices, for instance, a combination of research activity, teaching and consulting; simultaneous or consecutive employment in different sectors of economic activity; and participation in different types of international cooperation.

The sociology of social structure offers a base for the conceptual unification of separate parameters that can express the distribution of doctorates among different socio-professional, academic, bureaucratic and other positions along various criteria (Blau 1981; Ben-David and Sullivan 1975). Nevertheless, by virtue of the complexity and ambiguity of many aspects, an amorphous conceptual framework and a vague delimitation of the phenomenon borders, the problem of the sociological definition of the social mobility has yet to be solved.

In the framework of social structure, we can say the following of the social mobility of doctorate holders:

- the focus of the concept of the social mobility of a highly skilled scholar is an invariant form of the variant complex of his or her socio-structural features;
- the attempt to identify qualities of an doctorate's social position using the term "social mobility" conveys both general and unique meanings of the specific gain received from scientific capital within a range of socio-structural indicators;
- and the measure of a sample value of gain received from scientific capital can be presented in the form of a random sequence of probable outcomes of observing social mobility.

7.4 The Impact of Mobility on Growing Researchers' Scientific Capital

We use our empirical data to examine the factors that make the greatest contribution to the overall mobility of advanced degrees holders. The results of the correlation analysis showed a substantial link between the variable describing the size of the respondent's overall social mobility over the last 10 years and the set of variables linked to labor conditions and job satisfaction.

The most substantial link can be seen between social mobility and satisfaction with such labor conditions as wages and bonuses: more mobile doctorates are more satisfied with their wages and other payments in the form of raises and bonuses. In a number of surveys of doctorate holders in OECD countries [cf. for instance, the data given in Chap. 4 (Auriol, Misu, Galindo-Rueda) of this book], results have already been obtained which corroborate this positive correlation between mobility and wage levels. Mobility and satisfaction with opportunities for international collaboration are similarly interconnected, i.e. as expected, the more a respondent travels, changes jobs and combines different types of occupation, the more he or she is satisfied with international collaboration, and vice versa. A positive correlation can also be seen between mobility and the prestige of the work, i.e. the more mobile a respondent is, the more prestigious he or she considers the work in society and the more he or she is satisfied with the work as a whole.

Furthermore, the analysis shows the relationship between the value of the accumulated social mobility and the sector of employment: the most mobile turn out to be doctorate holders employed in industries which are currently not linked to their research, more often than not. This relationship suggests that the correlation between occupational mobility and social mobility and between occupational mobility and accumulated scientific capital may be negative. The most mobile doctorates, who have withdrawn from the academic sector into the business sector, often win in terms of wages, but lose out in social status and lose scientific capital. The ambiguous relationship between mobility and sector of employment is also confirmed in the case of professionals working in research institutes at the Russian Academy of Sciences and other specialized science academies. Workers at these organizations are less mobile in the domestic labor market compared with other doctorates, for example, in the higher education sector or industry, but they are more mobile in the international labor market. In addition, they have greater opportunities to raise their social status linked to a professional career in science and to grow their accumulated scientific capital.

It is worth noting the positive correlation between mobility and the early socialization of doctorate holders as researchers and experience in research projects. Such a career is most often associated with the academic labor market and stable employment in business and public sector organizations.

Next, we will discuss in greater detail certain driving forces behind a professional career and types of mobility among Russian advanced degrees holders.

7.5 Main Job-to-Job Mobility Trends of Doctorate Holders

Given the influential nature of the professional movements factor, we recorded in detail cases where people had changed their main place of work and the existence and nature of secondary employment over the last 10 years.

As shown by data from our dedicated monitoring survey, over the period 2000–2009 one in five scientists changed work, and in the period 2003–2012 their mobility increased with virtually one in four doctorate holders changing their place of work. This process has affected all age groups. Young PhD holders under 35 years of age changed their place of employment most intensively (42 %); among the middle-aged groups from 35 to 55 years, roughly 25 % changed their job at least once in the last 10 years, and for the older age groups this proportion is lower still. For example, in the 65–69 age group, only 20 % of doctorates changed jobs. This process affected 23 % of university teachers, 21 % of researchers at research institutes and more than half (56 %) of all doctorate holders employed outside the R&D sector in organizations in the public and business sectors (including financial, consultancy, audit, insurance and other commercial organizations, as well as in state and municipal government and state foundations supporting science and technology activities). Most of them changed their main place of work just once over the period under review.

What is interesting is that over the period since the previous wave of the survey (when movements from one work place to another were recorded over the period 2000–2009), the proportion of mobile doctorate holders increased from 19.6 to 24.8 %. This process affected doctorates employed outside the sciences the most as their share of all mobile doctorate holders increased from 20.7 % in 2009 to 34 % in 2012. Without a doubt industrial companies and organizations in the services sector have started to be mentioned more frequently as the place of employment of doctorates in Russia, which on the whole is in line with trends seen in other OECD countries (Fig. 7.1).

The survey revealed that the main area of occupational mobility is the higher education sector: 48 % of respondents who changed their main job in the period 2003–2012 went to work in higher education organizations, including 37.4 % in universities. We note that changes in participants' main place of employment mostly involve a move from one organization to another within the same sector, i.e. intrasectoral mobility dominates: for public sector organizations 43 % of movements are within the sector; for the business sector this figure is 51 %; and for the higher education sector it rises to 70.6 % (Fig. 7.2).

It should also be noted that one in four doctorate holders whose previous main place of work was associated with an R&D organization went to work in a higher education institution. At the same time, the number going in the reverse direction (from universities to research institutes), while considerably less in relative terms,

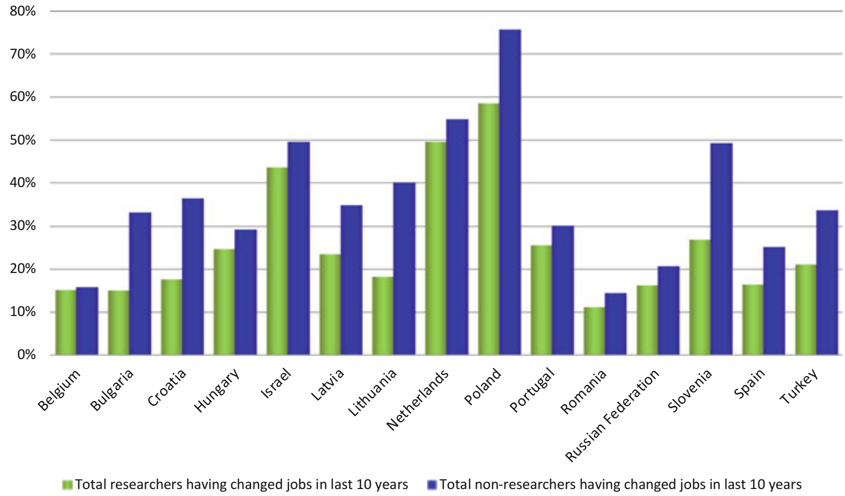
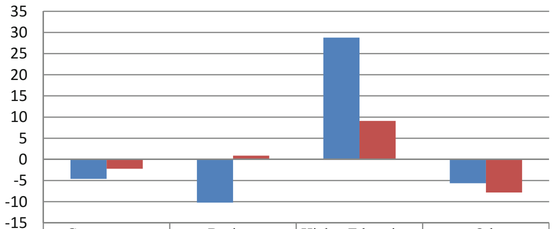


Fig. 7.1 Doctorate holders having changed jobs in the last 10 years, by research status, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010 (data for Russia - National Research University Higher School of Economics)



	Government	Business	Higher Education	Other
Balance 2009	-4.6	-10.2	28.8	-5.6
Balance 2012	-2.2	0.9	9.1	-7.8

Fig. 7.2 Inflow/outflow of doctorate holders mobility, by sector of employment, %. *Source*: National Research University Higher School of Economics based on survey data

was half as much again in absolute terms (the number of individuals). This might indicate indirectly that in recent years the prestige of research activity has risen in society and the conditions surrounding this field of work have improved.

On the whole, the group of professionally mobile doctorates, i.e. those who changed jobs at least once during the period under review, differs quite significantly in terms of their socio-demographic characteristics from the non-mobile group, i.e. those who never changed jobs during this period. In particular, theses differences relate to gender structure, average age, and place of residence and

Table 7.1 Main characteristics of the respondent subgroups based on level of occupational mobility

	Level of occupational mobility	
	Non-mobile	Mobile
Proportion of respondents in each subgroup, %	75.0	25.0
Gender structure:		
Proportion of men, %	53.0	63.0
Proportion of women, %	47.0	37.0
Age structure:		
Average age, years	48.0	44.2
Proportion of respondents by age, %:	100.0	100.0
20–29 years	8.3	14.8
30–39 years	23.0	29.6
40–49 years	18.0	18.2
50–59 years	27.7	22.7
60–69 years	23.0	14.7
Place of residence:		
Proportion of residents of Moscow, St. Petersburg, and the Moscow and Leningrad regions, %	37.0	46.2

Source: National Research University Higher School of Economics based on survey data 2010

work. The distribution of these characteristics is shown in Table 7.1. Clearly, in the "non-mobile" subgroup, there is a greater proportion of women, the average age is 4 years higher and, accordingly, there are significantly less doctorate holders under the age of 40. A substantial number (almost half) of all "mobile" doctorates life and work in the two main cities—Moscow and St. Petersburg—as well as directly adjoining regions.

One common view is that the frequently of changing jobs is directly linked to how well the work being carried out confirms to the scientific specialism. The suggestion is that a link between the work and a doctoral degree area helps to foster attachment to the work place. However, the results obtained in the CDH project show that the mere presence of absence of this link is not a sufficient factor in changing jobs.

This is corroborated by data on PhD holders in certain OECD countries. For instance, in Belgium almost one third of doctorates work in an area not related to their doctoral degree, while in Poland the percentage is only 6 %, and in Russia it is lower still—4.4 % (Table 7.2). At the same time, in Belgium the proportion of PhD holders who changed jobs over the last 10 years is relatively low (15.2 %), while in Poland it is high (63 %). As for Russia, in 2009 the percentage was roughly the same as Belgium (16 %), and then, in 2012, the proportion of doctorates who changed jobs in the last 10 years increased to 24.8 %. Thus, the link between the

Table 7.2 Employed doctorate holders' perception of job relation to their doctoral degree (2009, percentage of all respondents)

	Related	Partly related	Not related
Belgium	39.2	32.2	28.6
Bulgaria	84.7	10.7	4.7
Netherlands	41.5	39.5	19.0
Poland	76.8	17.2	6.0
Portugal	52.3	46.6	1.1
Russian Federation	73.6	21.9	4.4
Spain	63.6	20.5	15.9
Turkey	86.2	10.0	3.8
United States	65.7	26.0	8.3

Source: OECD, based on OECD/UNESCO Institute for Statistics/ Eurostat data collection on careers of doctorate holders, 2010 (data for Russia - National Research University Higher School of Economics)

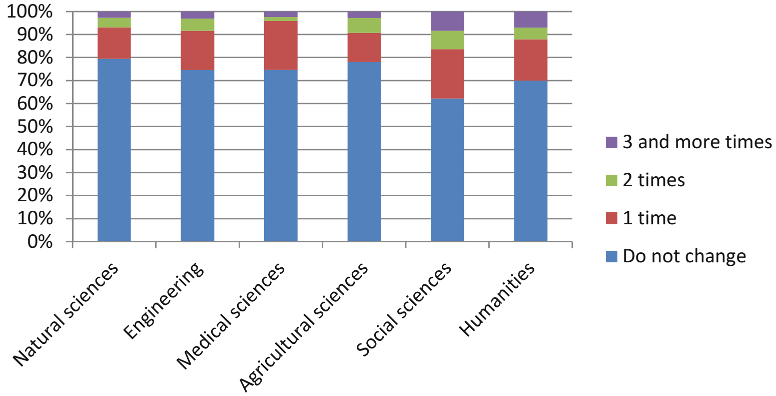


Fig. 7.3 Percentage of Russian doctorate holders having changed job in the past 10 years, by field of study. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders, 2010 (data for Russia - National Research University Higher School of Economics)

work itself and the field of the doctoral degree, taken in isolation, cannot explain the occupational mobility of PhD holders.

We consider the scientific specialization of doctorates as a factor affecting the frequency of changing jobs. The involvement of members of different scientific fields in this process is not the same (cf. Fig. 7.3). In Russia, advanced degrees holders in the social sciences change jobs far more frequently than those with PhD in the natural sciences. While 38 % of social science specialists changed their place of work at least once in the last 10 years, only 21 % of those in the natural sciences changed jobs.

7.6 Secondary Employment of Highly Qualified Research Personnel

Over the past two decades, secondary employment among researchers and professorial teaching staff at universities has become so widespread that it is now seen as being entirely normal. However, the reasons for secondary employment vary considerably depending on the position and professional qualities of PhD holders. For example, those who have high academic status can work in a variety of organizations as experts or managers, thereby validating previously acquired high social and professional skills. On the other hand, those who have not reached a high status use additional employment opportunities as an alternative to changing their main place of work. In both cases, doctorate holders are involved in secondary employment which differs in form and content.

The study has shown that more than 40 % of doctorates have an additional place of employment with an average service length of more than 10 years, which is suggestive of the stability of this phenomenon. It should be stressed that almost one in five doctorate holders who changed their main place of work in the period 2003–2012 already worked at the second job when moving to the new organization, and for longer than at their main job. However, the majority (80 %) worked at their main place of work longer than at their second job, i.e. the stability comes from their main place of work and the mobility comes from their additional employment, which is also relatively stable.

It should be noted that there is an extremely significant difference in the degree of involvement in secondary employment between researchers and non-researchers. In particular, the vast majority of non-researchers employed in business sector organizations (80 %) have only one job, while the percentage of university staff who do not have secondary employment is only 56 %, and among researchers working at research institutes this figure is 53 %. The proportion of those who have two or three places of work in this last group is higher than in other groups (Table 7.3).

According to the data, the main sector for secondary employment is higher education, which covers about 58 % of scientific staff with more than one job. However, the secondary employment of one in five PhDs is linked to the private sector, and for one in ten the public sector.

Table 7.3 Secondary employment of Russian doctorate holders be sector of employment, 2012

	Higher education	Research institutions	Business
Only one job	56	53	80
Two jobs	32	34	16
Three or more places of work	12	13	4
Total	100	100	100

Source: National Research University Higher School of Economics based on survey data

7.7 International Collaboration and International Mobility

The survey results show that only 15 % of Russian doctorates (of those now in Russia and excluding people that are currently abroad) have travelled abroad to study or work for more than 3 months during the course of their career. According to the CDH methodology, these respondents can be classified as "internationally mobile" and, by their very nature, are of particular interest from a research perspective.

The study examined the different characteristics of internationally mobile doctorate holders: general socio-demographic characteristics, the level and quality of education, employment, stages in their professional career, and performance in their professional activity, measured on the basis of bibliometric indicators and patent analysis.

The proportion of internationally mobile doctorates is relatively stable and is still at the same level as the results from the 2010 and 2013 surveys. The main destination of Russian doctorates' international mobility, as is the case for citizens of other OECD countries, is Europe. The second location is the United States of America. Next come Asian countries such as China, Singapore and Japan. In terms of Russian PhD holders, the total share of the group covering all countries excluding Europe and the US is more than 60 %. This reflects the nature of Russian doctorates' international movements, unlike those from, for example, Bulgaria or Romania (Fig. 7.4).

An important aspect of research personnel's mobility is their scientific specialization, which is obtained when preparing their dissertation. Among the "internationally mobile" group there are significantly more representatives from physics and mathematics (23.4 %) and biology (12 %). For comparison, in the "internationally non-mobile" group, only 14 % are from physics and mathematics and 7 % from biology. The "non-mobile" group is far better represented among engineering specialists (29 %) and economists (7.7 %). It could be argued that

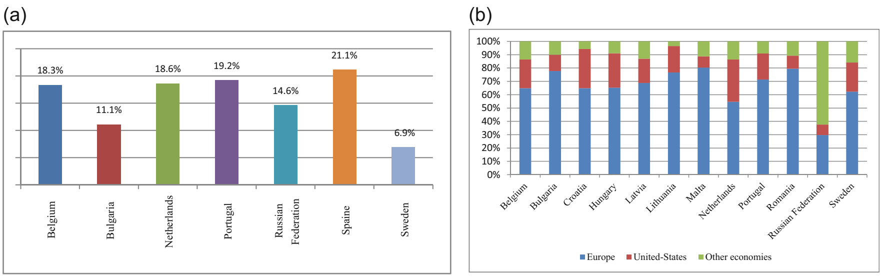


Fig. 7.4 National citizens with a doctorate having lived/stayed abroad in the past 10 years (2009). *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders, 2010 (data for Russia - National Research University Higher School of Economics)

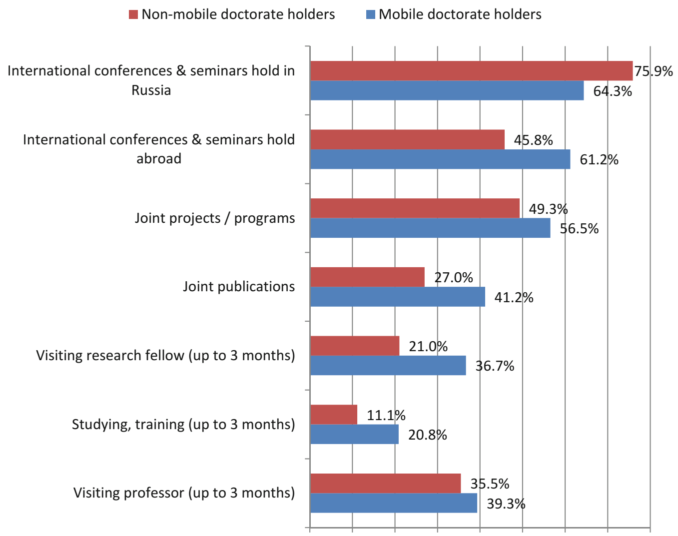


Fig. 7.5 Cross-border cooperation of doctorate holders (last 3 years), 2012. *Source*: National Research University Higher School of Economics based on survey data

engineering and economics specialists have greater opportunities for self-realization in the domestic labor market, while physicists, mathematicians and biologists have somewhat more opportunities for work in the international labor market.

It is worth stressing in particular that 83 % of Russian doctorates are involved in international collaboration. The most common form of international communication is research conferences, seminars and forums, which were attended by roughly 70 % of those surveyed (Fig. 7.5). In second place is working with foreign colleagues on joint publications (31 %) Third is involvement in joint research projects (27 %). So the least intensive forms of collaboration are the most common ones.

Comparison of the degree of involvement in international collaboration among research institute and university staff shows that scientists employed at research organizations are, on the whole, significantly more active and better integrated into international research networks. The gap in relation to joint publications is especially high. However, advanced degrees holders working in universities are more active in short-term (up to 3 months) trips abroad for lectures, internships or study.

Only 23 % were involved in international research projects and programs and 13.6 % in writing joint publications. Even fewer doctorates travelled abroad to study or for an internship (6.6 %) or for lectures (roughly 5 %). More detailed analysis shows that researchers from research centres are the most active in virtually all forms of international collaboration: among them only one in five do not take part in any research activities or joint programs. For advanced degrees holders employed in industry, the most accessible and common form of international collaboration is involvement in international conferences and seminars held on Russian territory.

The groups of respondents involved in, and not involved in, international links differ in terms of the number of publications they have. The “internationally mobile” doctorates have on average 30 publications in Russian journals for every individual, while non-mobile respondents have only 21 publications. Even more striking is the difference in the level of publication activity in foreign journals or books. Among the “internationally mobile” respondents 46.7 % have had publications in international journals within the last 3 years, while among the non-mobile respondents the figure is only 20 %. The situation is the same for publications in national and international monographs.

A comparison based on a full set of bibliometric indicators makes it possible to offer a fairly comprehensive assessment of the research output of doctorates which are involved and not involved in the network of international collaboration. However, for a more complete assessment of the potential of mobility, we need to move away from examining certain types of professional movements (intrasectoral, intersectoral, international) to a more complex and multifaceted phenomenon: social mobility. We will attempt to build a mathematical model which can help to explain how the different types of resources that doctorate holders accumulate during the course of their professional career are linked to their social mobility (see Appendix 2).

7.8 Distribution and Relationships between Scientific Capital and Social Mobility

The scatterplots for scientific capital and social mobility (Fig. 7.6) indicate a relatively close link between these two sociological values that is non-linear after a certain threshold. The value of the Pearson product-moment correlation coefficient $r = 0.639$ (the significance level p is 0.000) is about equal to the value of the Kendall rank correlation coefficient $\tau = 0.755\,(p = 0.000)$ and indicates a statistical dependence between scientific capital and social mobility. There is an increasing monotonic trend between scientific capital and social mobility: large scientific capital must show up as the bigger social mobility.

The empirical distribution of social mobility might be expected approximately the Pareto distribution $P(I)(0.00206,\ 3.343)$. The value of criterion z based on the Kolmogorov—Smirnov goodness-of-fit test was 0.593, and the p-value was 0.873. Because these values are satisfactory for a sociological study, we do not reject the statistical hypothesis of the Pareto distribution for social mobility.

As shown in our previous work (Katchanov and Shmatko 2014), the empirical distribution of scientific capital might be approximated as the lognormal $\Lambda(0.753,\ 0.132)$. The assumption that scientific capital is distributed according to the lognormal law was checked using the Kolmogorov—Smirnov goodness-of-fit test. The value of criterion z was 0.608 with a goodness of fit p-value of 0.850. This result can be considered appropriate for a sociological study. Therefore, we cannot

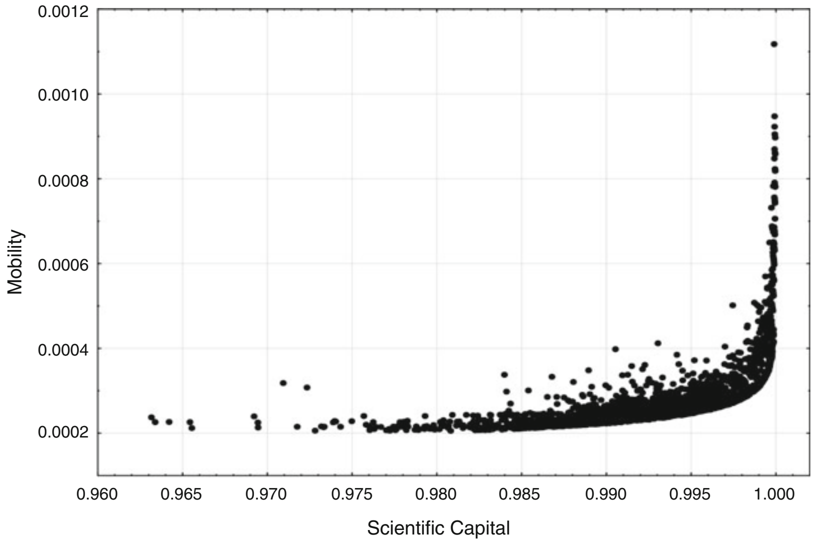


Fig. 7.6 Distribution of scientific capital and social mobility. *Source*: National Research University Higher School of Economics, based on survey data, 2012

reject the null hypothesis of the statistical lognormal distribution of scientific capital. In applied problems of mathematical statistics, with the help of lognormal distribution, a distribution of income under specific conditions is described (see, e.g., Atkinson and Bourguignon 2000; Lambert 2001; Sahota 1978), so an appearance of this distribution in the case of scientific capital is an indirect confirmation of the fact that the operationalization of this term was done correctly. Thus, the distribution of scientific capital can with some degree of reliability be qualified as lognormal that indicates the possible relevance of the variational principle of maximizing scientific capital.

There is a correlation between scientific capital and the age of the doctorate holders (the value of the Kendall rank-correlation coefficient τ is $0.671, p = 0.000$). This result is not surprising: we would expect people to accumulate capital. The first in-depth sociological study of "age, recognition and the structure of authority in science" was performed in 1972 by Merton and Zuckerman (Merton 1979, p. 497–559). In subsequent years, a more socially critical analysis of the age factor in an academic space was realized by Bourdieu (Bourdieu 1975, 1988). Since its theoretical introduction in 1972, a large amount of literature on the age factor in science has appeared. Thus it is quite natural that scientific recognition and administrative power increase, on a significant number of occasions, with an increase in the tenure of an agent in the academic space.

One might point to the gender effect on scientific capital with a certain confidence. The Spearman's rank correlation coefficient is $\rho = 0.723$ at a statistically significant level $p = 0.000$. Scientific capital values for men are on average higher than for women. This kind of statistic dependence is now a commonplace of sociology of science (see, e.g., Doerr 2004; Etzkowitz and Kemelgor 2001; Fox 1995; Penner 2015).

Since scientific capital can be modeled as a logarithmically normal distributed random variable, then scientific capital can be obtained as a multiplicative product of a large number of small, unrelated efficient causes; at that, the effect of each efficient cause is directly proportional to the actual value of scientific capital (Aitchison and Brown 1969, p. 22). Thus, we might assume scientific capital is influenced by many random positive valued actions, which results are independent and diminutive; these results determine the value of scientific capital multiplicatively rather than additively. In this context, multiplicative property means that each efficient cause has some effect on scientific capital and the result of this effect depends on the value of scientific capital that was already reached by the time when the efficient cause had been introduced. In this scheme, the main factor is the assumption that the influence of efficient cause on the intensity of the active properties will be directly proportional to the previously achieved intensity. Despite the divisiveness of this assumption, it has long had a place in the social sciences as "the Matthew effect" (Merton 1968). It follows that the sociological explanation for scientific capital must inevitably be historical; i.e., the multiplicativity of efficient causes occurs according to the historical development of scientific capital.

A characteristic feature of the lognormal distribution of scientific capital is the presence of large outliers, which indicates the structure-forming role of agents with small scientific capital and agents with large scientific capital in Russian academic space. In the lognormal distribution, small values for scientific capital are inseparable from high values. Thus, the presence of the first is an inevitable price to pay for the existence of the second. In this way, the existence of the two clusters of scolars, one related to high and the other related to low scientific capital, is not only a sufficient reason but also a mandatory condition for the current structure of the Russian academic space.

Let $f(\cdot)$ be the probability density function. The Pareto law

$$f(M) \propto M^a$$

indicates that the distribution of social mobility does not have a characteristic scale associated with it and is not organized as a dispersion of social mobility around some mean value that represents the center of the distribution (Clauset et al. 2009; Gabaix 2008). The self-similarity of the Pareto distribution can be described by the homogeneity of the probability density function of social mobility:

$$\left(\forall M', M''\right) : f\left(M'/M''\right) = M''^{a} f\left(M'\right),$$

i.e. the probability density function at any value M', relative to the probability density function at any other value M'', only depends on the ratio of M' to M'' and not the values themselves (Newman 2005). From a sociological point of view, the given formula might means that it is impossible to imagine the large values of social mobility as a sum (or a multiplicative product) of small efficient causes.

Figuratively speaking, social mobility can be thought as a specific gain from scientific capital. As is evident from Fig. 7.6, starting at an appointed value SC_0 (approximately $SC_0 = 0.95$), the connection between scientific capital and social mobility displays a pronounced non-linear character. De facto doctorates are allocated into two clusters, one of which is characterized by a high level of social mobility and another—by a relatively low one. The gap in values of social mobility between these clusters is determined not only by the quantity of scientific capital, but also by a constant multiplier. Apparently a significant deviation of the distribution of social mobility from the distribution of scientific capital can be conditioned by two heterogeneous social processes that provide a derivation of social mobility from scientific capital. Abnormal social mobility growth (after $SC_0 = 0.95$) stems from this heterogeneity. One can hypothesize that for large values social mobility may involve a mechanism that provides a scientific gain not only of scientific capital, but also of others forms of capital (political, bureaucratic, etc.).

7.9 Conclusions

The study revealed several principal trends in the labor market and careers of Russian doctorate holders:

Doctorates are relatively better than individuals with lower levels of educational attainment in terms of employment rates. Our study provides that one third of the respondents (36.4 %) have more than one job. Usually secondary employment relates to the higher education sector.

In comparison of the second international CDH data collection, the professional mobility of respondents has witnessed a steady increase: during last 10 years 25 % of researchers have changed their jobs. More than 40 % of them did it in the period of years 2010–2013, between second and third rounds of survey. At the same time work experience in the same organization is often more than 10 years. This attests long-term relationships between employers and highly skilled employees. The higher education sector remains as the main recipient of doctorate holders. Apparently the process of redistribution of highly skilled labor force is one of the consequences of governmental politics for integration of scientific research institutions and universities. It may be assumed this trend may remain the same in the nearest future.

A thorough review and analysis of the data obtained leads to the conclusion that "internationally mobile" doctorates are a quite clearly definable subgroup among all highly qualified specialists working in research and higher education. For the most part, this group is made up of men working in public sector organizations. They have well developed links with specialists from other countries and, thanks to their social capital and academic power, have greater opportunities to work in these countries and to prepare joint research publications and patents. The incomes of "internationally mobile" respondents are on average higher, but they also have higher employment levels. Specialists such as these are firmly integrated into the international research publications system and submit patent applications and obtain patents more frequently than other Russian doctorate holders.

A power type of social mobility dependence from scientific capital points out the feedback between them: the greater scientific capital, the higher social mobility is, which, in turn, leads to an increase in scientific capital. This can be interpreted that there is a stochastic growth process in which the social mobility is determined by scientific capital and by time which the agent stays in academic space.

Non-linearity of dependence between scientific capital and social mobility is explained by the fact that the lognormal distribution of scientific capital differs dramatically from the Pareto distribution of social mobility (Uchaikin and Zolotarev 2011). While the first probability distribution is typical for the simple systems formed by a set of independent elements, the second probability distribution observed for the complex systems, where, on the contrary, there are no independent elements (Mitzenmacher 2004). Consequently, if doctorates accumulate scientific capital mostly individually, then they accomplish social mobility mostly socially.

The Russian academic space has a fairly modest for influence on social mobility of the agents since the mobility type is rather defined by economic and social reasons. This implies that structures of an academic space are not determinative for the achievement of optimal mobility by personnel, i.e. its desire for increased mobility is not limited to the factors of an academic nature but is formed under the impact of socio-economic conditions which are random towards the space. We believe that this result will motivate further studies to uncover the origin of the relationship between socio-economic factors and scientific activities in Russia.

Appendix 1. Variables Related to Scientific Capital and Social Mobility

I Scientific Capital set

1. “Symbolic power”—the active properties that provide the respondent with the ability to apportion other signs of scientific recognition:
   (1) biography published in the Russian encyclopedia/handbook
   (2) biography published in the international/foreign encyclopedia/handbook
   (3) public conference/talk in Russia
   (4) public conference/talk in foreign countries
   (5) publications in the media
   (6) speech on the radio or on television
   (7) publications about him/her in the media (interviews, reviews, etc.)
   (8) personal blog or site on the Internet
   (9) citation index
   (10) number of peer-reviewed articles in leading Russian journals

(11) number of peer-reviewed articles in leading international journals (Web of Science, Scopus, etc.)
(12) monographs in a national publisher house
(13) monographs in a foreign publisher house
(14) translations of his or her work into foreign languages
(15) patents
(16) scientific and academic awards from Russia and other countries
(17) personal grants received
(18) number of the foreign languages used by respondent in professional communication (reading literature, presentations or lectures, writing papers)

2. "Bureaucratic power"—the active properties that allow the respondent access to institutional resources:
(19) participation in scientific councils
(20) membership on editorial boards
(21) membership in governmental/national expert boarding/council
(22) membership in committee on graduate programs for graduate theses
(23) assignment to administrative posts connected with the distribution of employment and financial resources
(24) administrative posts connected with management of national and international scientific and educational projects
(25) leading position at university/research institution

3. "Academic power"—the active properties that enable control of the social reproduction of the corps of scientists:
(26) membership in professional organizations/associations
(27) membership in governmental/national expert boarding/council
(28) membership in thesis/dissertation examining committee
(29) supervision of dissertations
(30) number of doctorate awarded under his/her supervision

4. Post-graduate training/retraining:
(31) courses, trainings, seminars in own or related areas
(32) courses, trainings, seminars in other areas of specialization
(33) courses, trainings, workshops in management, planning, etc.
(34) computer courses in certain software products
(35) foreign languages courses

II Social Mobility set

1. Labor autonomy:
(1) leadership/supervision of other employees
(2) number of personnel under his/her supervision
(3) participation in decision-making about recruitment or dismissing an employee of respondent's unit
(4) allocation of duties
(5) negotiating the terms of contracts/orders from customers
(6) participation in decision-making in choosing a supplier, contractor

(7) autonomy in determining the timing of the job
(8) autonomy in determining the schedule
(9) autonomy in determining the composition/volume of required work
(10) autonomy in the choice of methods/technologies/materials

2. Access to financial resources:
(11) management of educational and/or implementation projects
(12) management/participation in research programs funded from state
(13) management/participation in research programs funded from non-budget sources

3. Career path:
(14) early professionalizing, entrance to professional activity during study at university: full-time/part-time work or side job related to specialty
(15) participation in research projects during study
(16) relation of first job to university diploma
(17) relation of present principal job to advanced research qualification
(18) change of field of science during last 10 years
(19) professional mobility during last 10 years (job-to-job mobility)
(20) current position on the scale of professional attainments: from an assistant to a head of institution (present principal job)
(21) rate of moving up the "career ladder"
(22) availability of additional work
(23) relation of second job to advanced research qualification
(24) current position on the scale of professional attainments: from an assistant to a head of institution (second job)
(25) sector of employment for principal and second job (business enterprises, government, higher education, other education, private non-profit organizations)
(26) occupation in the principal and the second job
(27) total job tenure
(28) seniority in a scientific or research position

4. "International career":
(29) teaching activity (visiting professor), stay abroad up to 3 months
(30) research activity (visiting research fellow), stay abroad up to 3 months
(31) studying, training at foreign organizations (up to 3 months)
(32) working on a joint publication with foreign authors
(33) working on a joint projects, programs with researchers in another country
(34) participation in international conferences, seminars, other events held abroad
(35) participation in international conferences, seminars, other events held in Russia

5. Level of wealth and consumption:
(36) principal job salary
(37) annual income
(38) consumption level of the family
(39) number of dependent children

Appendix 2. Operationalisaing Social Mobility

The operationalization of social mobility should occur as follows:

- ideally, social mobility should be expressed of one number,
- comprehensive character—social mobility should incorporate all of the collected sociological information on the total shifts of the doctorate holder, and
- systemic—social mobility should establish a correspondence between the social shifts of all of the doctorate holders in the sample.

The approach outlined below attempts to introduce the concept of social mobility that will satisfy these criteria.

For the sake of brevity, we only discuss the set $\{I_k\}_{k=1}^{k=m}$ of indicators that characterize the social shifts in the sample S_N. Obviously, in this case, the sociological information on the sample S_N can be written as $m \times N$-matrix I_N^m, which consists of m columns and N rows. However, we can present the information contained in I_N^m in another way: as $N \times N$-matrices U, which characterizes the system of social differences that exist between the total social shifts in the sample S_N. The mapping $I_N^m \to U$ is bijective. The element u_{ij} of the matrix U corresponds to the conditional probability that social mobility of the j-th respondent is more than social mobility of the i-th respondent. Then the matrix U has non-negative entries and the row sums are equal to one

$$(\forall i, j \in S_N) : 0 \leq u_{ij} \leq 1,$$

$$(\forall i \in S_N) : \sum_{J \in S_N} u_{ij} = 1.$$

For complete certainty, it suffices to demonstrate the method of calculating u_{ij} based on the results of sociological measurement

$$(\forall i, j \in S_N) : u_{ij} = \frac{d_{ij}}{\sum_{j \in S_N} d_{ij}},$$

where d_{ij} denotes the value of the uniform metric which establishes a measure of proximity between the i-th doctor and the j-th doctor in the space of their social shifts.

Social mobility is actively involved in the production of academic space in order to move social structures of science and academia forward. Accordingly, there is some reason to interpret the value of the respondent's social mobility as a probability of his or her upward mobility. We denote this probability as M_j. As follows from the ergodic theorem for Markov chains with a countable state space (Borovkov 2013, p. 404–405), the probabilities $\{M_j\}_{j \in S_N}$ are the unique solution of the system

$$\sum_{j \in S_N} M_j = 1,$$

$$M_j = \sum_{i \in S_N} M_j u_{ij}$$

in the class of absolutely convergent series. Social mobility M_j is a function of the social shifts of the PhD holder. Analyzing the ergodic theorem for Markov chain it is easily to see that the more is the volume of the social shifts, the more is the value of M_j, although the relationship between the two is non-linear.

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References

Aitchison J, Brown JAC (1969) The lognormal distribution, with special reference to its uses in economics. Cambridge University Press, Cambridge

Altbach P (1996) The international academic profession: portraits of fourteen countries. Carnegie Foundation Press, Princeton, NJ

Atkinson AB, Bourguignon F (2000) Income distribution and economics. In: Atkinson AB, Bourguignon F (eds) Handbook of income distribution, vol 1. Elsevier, Amsterdam, pp 1–58

Auriol L (2007) PhD holders: labour market and international mobility. Foresight-Russia 1(3): 34–48

Auriol L (2010) Careers of doctorate holders: employment and mobility patterns. In: OECD Science, Technology and Industry working papers 2010/04. OECD Publishing, Paris. doi: http://dx.doi.org/10.1787/5kmh8phxvvf5-en

Auriol L, Misu M, Freeman R (2013) Doctorate holders: labor market and mobility indicators. Foresight-Russia 7(4):16–42

Bellotti E (2011) The social processes of production and validation of knowledge in particle physics: preliminary theoretical and methodological observations. Procedia Soc Behav Sci 10: 148–159. doi:10.1016/j.sbspro.2011.01.018

Ben-David J, Sullivan TA (1975) Sociology of science. Annu Rev Sociol 1:203–222

Blau PM (1981) Diverse views of social structure and their common denominator. In: Blau PM, Merton RK (eds) Continuities in structural enquiry. Sage, London, pp 1–23

Borovkov AA (2013) Probability theory. Springer, London. doi:10.1007/978-1-4471-5201-9

Bourdieu P (1975) The specificity of the scientific field and the social conditions of the progress of reason. Soc Sci Inf 14(6):19–47. doi:10.1177/053901847501400602

Bourdieu P (1984) Distinction: a social critique of the judgement of taste. Harvard University Press, Cambridge, MA

Bourdieu P (1985) The social space and the genesis of groups. Theory Soc 14(6):723–744. doi:10.1007/BF00174048

Bourdieu P (1988) Homo Academicus. Stanford University Press, Stanford, CA

Bourdieu P (1989) Social space and symbolic power. Sociol Theory 7(1):14–25

Bourdieu P (1991) The peculiar history of scientific reason. Sociol Forum 6(1):3–26. doi:10.1007/BF01112725

Bourdieu P (1992) The logic of practice. Stanford University Press, Stanford, CA

Bourdieu P (1997) Les usages sociaux de la science: Pour une sociologie clinique du champ scientifique. INRA, Paris
Bourdieu P (2002) The forms of capital. In: Biggart NW (ed) Readings in economic sociology. Blackwell, Malden, MA, pp 280–291
Bourdieu P (2004) Science of science and reflexivity. University of Chicago Press, Chicago, IL
Bourdieu P, Wacquant LJD (1992) An invitation to reflexive sociology. University of Chicago Press, Chicago, IL
Bozeman B, Corley E (2004) Scientists' collaboration strategies: implications for scientific and technical human capital. Res Policy 33(4):599–616. doi:10.1016/j.respol.2004.01.008
Bozeman B, Dietz JS, Gaughan M (2001) Scientific and technical human capital: an alternative model for research evaluation. Int J Technol Manag 22(7):716–740
Brosnan C (2011) The significance of scientific capital in UK medical education. Minerva 49(3): 317–332. doi:10.1007/s11024-011-9177-z
Brubaker R (2005) Rethinking classical theory. In: Swartz D, Zolberg V (eds) After Bourdieu: influence, critique, elaboration. Springer, Dordrecht, pp 25–64. doi:10.1007/1-4020-2589-0_3
Calhoun C (1993) Habitus, field, and capital: the question of historical specificity. In: Calhoun C, LiPuma E, Postone M (eds) Bourdieu: critical perspectives. University of Chicago Press, Chicago, IL, pp 61–88
Camic C (2011) Bourdieu's cleft sociology of science. Minerva 49(3):275–293. doi:10.1007/s11024-011-9176-0
Clauset A, Shalizi CR, Newman ME (2009) Power-law distributions in empirical data. SIAM Rev 51(4):661–703. doi:10.1137/070710111
Coradini OL (2010) The divergences between Bourdieu's and Coleman's notions of social capital and their epistemological limits. Soc Sci Inf 49(4):563–583. doi:10.1177/0539018410377130
Corolleur CD, Carrere M, Mangematin V (2004) Turning scientific and technological human capital into economic capital: the experience of biotech start-ups in France. Res Policy 33(4): 631–642. doi:10.1016/j.respol.2004.01.009
D'Agostino A, Calmand J, Moncel N, Sulzer E, Lozier F (2009) Intégrer l'entreprise privée avec un doctorat: l'exemple de la branche ingénierie, informatique, études et conseil. Bref Céreq 268:1–4
Dhondt-Peltrault E (2010) R&D et structure des entreprises: une comparaison France/États-Unis. Centre d'Analyse strategique. La Note de veille 173: Avril
Dietz JS, Bozeman B (2005) Academic careers, patents, and productivity: industry experience as scientific and technical human capital. Res Policy 34(3):349–367. doi:10.1016/j.respol.2005.01.008
Doerr L (2004) Women's work: gender equality vs. hierarchy in the life sciences. Lynne Rienner Publishers, Boulder
Etzkowitz H, Kemelgor C (2001) Gender inequality in science: a universal condition? Minerva 39(2):239–257. doi:10.1023/A:1010337925943
Fox MF (1995) Women and scientific careers. In: Jasanoff S (ed) Handbook of science and technology studies. Sage, Thousand Oaks, CA, pp 205–223
Fox MF, Mohaparta S (2007) Social-organisational characteristics of work and publication productivity among academic scientists in doctoral-granting departments. J Higher Educ 78(5):542–571
Gabaix X (2008) Power laws in economics and finance (w14299). National Bureau of Economic Research. http://www.nber.org/papers/w14299. Accessed 3 Feb 2015
Garforth L, Kerr A (2011) Interdisciplinarity and the social sciences: capital, institutions and autonomy. Br J Sociol 62(4):657–676. doi:10.1111/j.1468-4446.2011.01385.x
Gokhberg L, Kitova G, Kuznetsova T, Shuvalova T (2010) Rossijskie uchenye: shtrikhi k sotsiologicheskomu portretu [Russian scientists: Sketches to a sociological portrait]. HSE, Moscow (in Russian)
Goldthorpe J (1987) Social mobility and class structure in modern Britain. Clarendon, Oxford
Grossetti M (1986) Metaphore economique et economie des pratiques. Rech Sociol 17(2):233–246

Heckathorn DD (1997) Overview: the paradoxical relationship between sociology and rational choice. Am Sociol 28(2):6–15. doi:10.1007/s12108-997-1002-7

Hong W (2008) Domination in a scientific field: capital struggle in a Chinese isotope lab. Soc Stud Sci 38(4):543–570. doi:10.1177/0306312706092456

Jain S (2013) Bourdieu's sociology: a post-positivist science. Thesis Eleven 117(1):101–116. doi:10.1177/0725513613492589

Jonkers K (2008) A comparative study of return migration policies targeting the highly skilled in four major sending countries. European University Institute, San Domenico di Fiesole

Jonkers K, Tijssen R (2008) Chinese researchers returning home: impacts of international mobility on research collaboration and scientific productivity. Scientometrics 77:309–333

Kachanov Yu, Shmatko N (2011) Struktura mobil'nosti nauchnykh kadrov vysshej kvalifikatsii: kontseptual'naya model' i rezul'taty issledovaniya [The structure of the mobility of highly qualified scientific personnel: a conceptual model and research outputs]. Universitetskaya kniga, Moscow (in Russian)

Katchanov YL, Shmatko NA (2014) Complexity-based modeling of scientific capital: an outline of mathematical theory. Int J Math Math Sci 2014:10. doi:10.1155/2014/785058

Knight J (1995) Internationalization at Canadian Universities: the changing landscape (L'internationalization dans les universites Canadiennes: le nouveau paysage). Association of Universities and Colleges of Canada, International Relations and Programs

Kroneberg C, Kalter F (2012) Rational choice theory and empirical research: methodological and theoretical contributions in Europe. Annu Rev Sociol 38:73–92. doi:10.1146/annurev-soc-071811-145441

Kulakova A, Roshchina Ya (2010) Tipologiya I factory "portfelej rabot" rossijskikh uchenykh [Typology and Factors of Work Portfolios of Russian Scientists]. Foresight-Russia 4(4): 42–55 (in Russian)

Lambert PJ (2001) The distribution and redistribution of income. Manchester University Press, Manchester

Lebaron F (2001) Economists and the economic order: the field of economists and the field of power in France. Eur Soc 3(1):91–110. doi:10.1080/14616690120046969

Lebaron F (2003) Dispositions, social structures and economic practices: towards a new economic sociology. In: Fullbrook E (ed) Intersubjectivity in economics: agents and structures. Routledge, New York, pp 231–240

Lenoir R (2006) Scientific habitus: Pierre Bourdieu and the collective intellectual. Theory, Cult Soc 23(6):25–43. doi:10.1177/0263276406069774

Lipset SM (1959) American intellectuals: their politics and status. Daedalus 88(3):460–486

Lipset SM, Bendix R (1992) Social mobility in industrial society. Transaction Publishers, New Brunswick, NJ

Matthys M (2012) Cultural capital, identity, and social mobility. Routledge, New York, pp 126–164

Merton RK (1968) The Matthew effect in science. Science 159(3810):56–63. doi:10.1126/science.159.3810.56

Merton RK (1979) The sociology of science: theoretical and empirical investigations. University of Chicago Press, Chicago, IL

Mitzenmacher M (2004) A brief history of generative models for power law and lognormal distributions. Int Math 1(2):226–251. doi:10.1080/15427951.2004.10129088

Musselin C (2005) European academic labor markets in transition. High Educ 49:135–154

Newman ME (2005) Power laws, Pareto distributions and Zipf's law. Contemp Phys 46(5): 323–351. doi:10.1080/00107510500052444

Panofsky AL (2011) Field analysis and interdisciplinary science: scientific capital exchange in behavior genetics. Minerva 49(3):295–316. doi:10.1007/s11024-011-9175-1

Penner AM (2015) Gender inequality in science. Science 347(6219):234–235. doi:10.1126/science.aaa3781

Ruget V (2002) Scientific capital in American political science: who possesses what, when and how? New Polit Sci 24(3):469–478. doi:10.1080/0739314022000005464

Sahota GS (1978) Theories of personal income distribution: a survey. J Econ Lit 1:55
Saito K, Misu T, Tsunoda H (2008) Survey on postdoctoral fellows and research assistants (FY2006 Data). NISTEP, Research Material 156: August
Sen AK (1977) Rational fools: a critique of the behavioral foundations of economic theory. Philos Public Aff 6(4):317–344
Sismondo S (2011) Bourdieu's rationalist science of science: some promises and limitations. Cult Sociol 5(1):83–97. doi:10.1177/1749975510389728
Sivak E, Yudkevich M (2009) Akademicheskij inbriding: za i protiv [Academic Inbreeding: Pro and Contra]. Voprosy obrazovaniya [Educational Studies] 1:170–187 (in Russian)
Sorokin PA (1927) Social mobility. Harper & Brothers, New York and London
Suslov A (2010) Planirovanie nauchnoj kar'ery: vzglyad skvoz' prizmu sotsiologicheskogo obsledovaniya [Planning a scientific career: a view through the prism of a sociological survey]. Voprosy statistiki 8:21–35 (in Russian)
Uchaikin VV, Zolotarev VM (2011) Chance and stability: stable distributions and their applications. Walter de Gruyter, Berlin. doi:10.1515/9783110935974
Wacquant L (2011) Habitus as topic and tool: reflections on becoming a prizefighter. Qual Res Psychol 8(1):81–92. doi:10.1080/14780887.2010.544176

International Mobility of Spanish Doctorate Holders

8

Laura Cruz-Castro, Koen Jonkers, and Luis Sanz-Menéndez

8.1 Introduction

In this section we present the aims of the chapter, the relevance of the issue, and some references to the literature and previous studies. Science policy makers and analysts tend to consider international mobility as a positive phenomenon which deserves to be (and increasingly is) promoted (EC 2000, 2001a, b, 2005, 2011, 2012a, b; Morano-Foadi 2005; Ackers 2008). This is reflected in the programs and policy initiatives by national governments and the EU to promote international scientific mobility such as the Marie Curie Actions[1] and the European Charter for Researchers and The Code of Conduct for the Recruitment of Researchers (EC 2005, 2012a, b; Ackers 2008). Analysts associate international mobility with the diffusion of knowledge and capacity building (Ackers 2005; Edler et al. 2011; Jonkers and Cruz-Castro 2013), research collaboration (Fontes 2007; Jonkers and Tijssen 2008; Melkers and Kiopa 2010; see also EC 2012a, b) as well as productivity (Edler et al. 2011; Defazio et al. 2009; De Filippo et al. 2009).

A recent OECD study on the 2009 Careers of Doctorate Holders (CDH) survey (Auriol et al. 2013) reveals that in the countries for which data is available, an

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[1] The Commission proposes to raise the budget of the Marie Curie actions by 21 % to 5.75 billion euro in Horizon 2020 (EC 2011).

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average of 14 % of doctorate holders have been mobile in the previous 10 years; the authors acknowledge that this could be a relatively low estimate since the data are based on declarations of returnees and do not include those who remain abroad. In any case this apparently low mobility rate may also be explained by a number of barriers which have been traditionally recognised, including economic and personal costs or lack of incentives. As regards motivations, it is noteworthy that academic reasons play an important role in the decision to go abroad and, in general, those doctorate holders who work as researchers as well as those who work in the higher education sector are more mobile. International mobility has been considered by the literature both a phenomenon to explain, and also as an explanatory or independent factor of other career dynamics, including research productivity at the individual level.

Using data from the Spanish CDH survey, this study first explores which variables are associated with the likelihood of Spanish doctorate holders to have engaged in international mobility. The literature has identified a number of push and pull factors and the CDH survey contains information about many of them. Our analysis considers some socio-economic variables together with some trajectory ones: the age of respondents, the timing of their PhD degree by dividing the sample in different cohorts, the nationality of respondents, gender, the way in which the doctorate was financed, the field of doctorate study as several studies have shown that mobility patterns differ between fields [in Spain Cañibano et al. (2008, 2011), De Filippo et al. (2009), in Belgium Vandevelde (2011), in the EU Jöns (2007) and IDEA Consult et al. (2010)], whether someone was exclusively engaged in fundamental research or exclusively engaged in applied research during their PhD, and the number of months it took respondents to complete their doctorate.

Secondly, considering international mobility as an independent or explanatory factor of other career dynamics, the chapter explores the variables associated with the likelihood of PhD holders to be engaged in research. This issue is important as it may partly reflect the returns of the social investments in doctoral education into the R&D system. Bearing in mind that international experience might increase scientific and technical human capital (Bozeman and Corley 2004; Ponomariov and Boardman 2010) and also that international mobility is considered to be one of the scientist's potential strategies to increase his/her access to collaborators, knowledge and skills (Edler et al. 2011), the expectation is that those who have experience of international mobility are also likely to be those who are engaged in research, but other factors may play a role which will therefore be considered as controls.

The chapter continues by analysing mobility in relation to the broader issue of the research career and looks at the association between international mobility experience and the likelihood of having obtained permanent or tenured employment. Ackers argues that not only has international mobility for a long time been an integral part of research employment trajectories, but that it has almost become considered a prerequisite for successful scientific careers (though there are differences between countries and disciplines in this respect). The acquisition of knowledge and experience is a clear motivation for researchers to engage in international mobility (Leyman et al. 2009). Enders and Musselin (2008) argue that motivations for international mobility include the improvement of their labor market chances in their home system and socio-economic advancement. On the other hand there are empirical studies (in specific countries) which show that there is little, if any, positive effect of international mobility in the early stages of the academic career on early advancement to tenure. Due to some structural and institutional features of national academic systems, the effect of mobility may even be negative for the time to tenure (Sanz-Menéndez et al. 2013).

Indeed the EC (2007) recognised in its green paper with new perspectives on the ERA, which advocates greater scientific mobility, that “Mobility across borders [. . ..] tends to be penalised rather than rewarded” (EC 2007, p. 12). This may be related to the point made by Ackers (2008) that international scientific mobility may also be “forced”upon researchers due to the shortage of (permanent) research positions in their home system. She argues that such push factors may actually be more important as a driver for international mobility than the occasions in which people actively choose to invest in the development of their scientific and technological human capital through the decision to engage in international mobility. Enders and Musselin (2008) also highlighted that such push factors were an important motivation for international mobility for some groups of researchers. The importance of this motivation versus the previously mentioned motivations is likely to differ between research systems.

Also in systems in which international mobility is valued, international mobility may only have a positive effect on the speed of career development in academia if it is associated with a significantly higher productivity or visibility.[2] Unfortunately it is not possible to control for this in the current study. Apart from potential gains in terms of increased network ties and potentially greater access to resources and know-how (IDEA Consult et al. 2010), there may also be costs involved in international mobility due to higher transaction costs, as well as the loss of time, opportunities and contacts in the home system.

In the case of Spain the effect of international mobility on career development has been explored previously (Cruz-Castro and Sanz-Menéndez 2010; Sanz-Menéndez et al. 2013). These studies based their results on a different dataset, restricted to researchers with permanent positions in governmental sector research institutes (the CSIC) and universities. The larger dataset used for the present study considers all sectors in which doctorate holders are employed in Spain. A potential advantage of the present dataset is that it is not limited to those who have already obtained permanent research positions, but include most doctorate holders including those who have not obtained this position and those working in other sectors. As highlighted by both Ackers (2008) and Ferro (2006) it is important to consider both researchers who have been mobile and those who were immobile during the period

[2] While according to Ackers (2008) it is clear that the quality of the mobility experience is often less important than the fact of mobility—this would need to be tested empirically in the context of different European countries. A study in Argentina suggests that this may not hold true here (Jonkers 2011).

under study. However, an important limitation of the current study in comparison to the papers by Cruz-Castro and Sanz-Menéndez (2010) and Sanz-Menéndez et al. (2013) is that we do not consider productivity data which is often expected to be associated with the speed of career advancement in research and academia.

The final part of the study analyses the effect of several variables on the stated intention to move in the year following the survey. These variables include: previous postdoctoral international mobility experience in the past 10 years, whether someone has dependents or not, gender, earnings, the sector in which respondents are employed at the time of the survey, professional category, teaching loads, the relationship between their current job and their doctorate, whether they are working part time or full time, whether they are on a temporary or a permanent contract, whether they have set up their own company and whether they have engaged in international collaboration. These variables are commonly used in PhD careers' studies and national doctorate holders' surveys.

8.2 Empirical Questions and Expectations

More concretely, this chapter aims to address some questions which we believe are especially interesting from a policy perspective:

- Which factors can help explain the likelihood that Spanish doctorate holders have engaged in past international mobility?
- To what extent is international mobility (and various other variables) associated with the likelihood of respondents being engaged in research?
- To what extent is international mobility (and various other variables) associated with the likelihood of the advancement of doctorate holders to a permanent position?
- Which factors can help explain the likelihood that Spanish doctorate holders intend to move in the immediate future?

In line with some previous studies, we expect that male (Leyman et al. 2009; IDEA Consult et al. 2010), younger respondents (IDEA Consult et al. 2010), who have completed their degree recently in a relatively short time (a proxy for of the rate of educational progress), and those working in the Higher Education sector (IDEA Consult et al. 2010) are the ones who show the highest propensity for international mobility. We may also expect that natural science doctorate holders and those engaged in fundamental research during their doctorate are relatively more mobile than doctorate holders in other fields (Vandevelde 2011) and than those engaged in applied research. The reason behind this expectation is that fundamental research is likely to be more international in nature whereas applied research may in many cases be embedded in a local or national context. It is also expected that those whose PhD was funded through a fellowship tend to have higher levels of mobility because having obtained a fellowship involves, in general, a positive evaluation of a potential for a successful research career and because they are likely to be more successful in obtaining subsequent funding for international mobility.

Finally, one would expect that those with temporary contracts are generally more likely to be mobile than those with permanent positions; however this also depends on the specific features of the national academic employment system. In this respect, as shown by Cruz-Castro and Sanz-Menéndez (2010) and Sanz-Menéndez et al. (2013) international mobility experience appears to have a negative effect on the speed of obtaining tenure in Spanish academia and for this reason it is a possibility that doctorate holders in the Spanish context will try to postpone their international mobility experiences to a later stage in the research career when they have already obtained a permanent contract.

Another expectation is that controlling for other factors previous international mobility experience has a positive effect on the likelihood of individuals to consider to move internationally in the near future. The same is expected to hold for people without a permanent position (however the nature of the career structure Spanish system may alter this). The MORE survey provides some relevant findings in this respect (IDEA Consult et al. 2010). Firstly, it reveals that 55 % of the respondents to the survey, who did not report mobility, had considered future mobility. Secondly among those without international mobility experience it shows that it is post-docs who are most likely to have considered future mobility.

The expectation is that those with previous experience of postdoctoral international mobility are more likely to be engaged in research than those without (Vandevelde 2011). As was discussed in the introduction, research is often thought of as a highly internationalised profession, although there are other professions that are also highly internationalised, such as managers in multinational companies. Overall however, non-researchers in both the private and public sector in Spain are expected to be less mobile than those engaged in research. Academic reasons play an important role in the decision to go abroad and some preliminary results of the CDH micro data work also reveal that those doctorate holders who work as researchers as well as those who work in the higher education sector are more mobile than the others (Auriol et al. 2013, p. 38).

Finally, on the one hand, on the basis of previous studies (Cruz-Castro and Sanz-Menéndez 2010) we expect that, in Spain, international mobility, controlled for by other factors, is not likely to have a positive effect on being employed in a permanent position accounting for differences between cohorts. On the other hand, however, the results of the MORE survey (IDEA Consult et al. 2010) indicate that a large share of European scientists believes that their international mobility experience has had a positive impact on their career.

8.3 Methodology

This study uses data from the Spanish CDH survey implemented in 2006 with a sample of 12,625 doctorate holders who had obtained their PhD degree between 1990 and 2006 and were under 70 years of age. Although the questionnaire provides information about trajectory variables based on recollections or on statements about intentions, it must be acknowledged that the data is transversal and not longitudinal.

For the definition of having “international mobility experience” use is made of definition 12 of the CDH survey handbook (Auriol et al. 2010): “An internationally mobile advanced research qualification holder is an advanced research qualification holder who, since the award of his/her advanced research qualification, has moved to a country other than that of his or her usual residence for a period of at least 3 months”.

We have first made some cross tabulations between international mobility and some variables of interest to get some descriptive analyses. Secondly, acknowledging that many factors can have an influence on international mobility it is important to assess the effect of the relevant factors net of other variables. For this purpose a series of logistic regression analyses were carried out in which international mobility is considered as the dependent variable in some cases and an independent explanatory factor in others. Our data comes from the OECD CDH surveys implemented by the National Statistics Institute of Spain (INE) in 2006 and 2009.[3] The 2006 sample which is used in this chapter was answered by a sample of 12,525 doctorate holders who obtained their PhD from a Spanish University and resided in Spain at the time of the survey. The sample was weighted according to regions so that the total adapted sample size used in this analysis includes 12,625 observations. For some analyses a more restricted sample was used.

The sampling strategy has some limitations that are important to acknowledge in a study of international mobility. First, the sample of respondents is limited to people who have obtained their PhD from Spanish universities. Foreigners and Spanish citizens who have obtained their PhD from a university outside of Spain, but who are currently working back in the country are therefore not considered in this study. Another limitation is that those who have obtained their PhD from a Spanish university, but resided in a different country at the time of the survey are not included either. In combination these limitations are likely to have resulted in a low share (17.3 %) of the mobile population of doctorate holders in Spain and/or of Spanish doctorate holders worldwide. Table 8.1 provides the descriptive statistics for the variables considered.

8.4 Results

8.4.1 International Mobility Experience: Descriptive Cross Tabulations

The levels of international mobility experience among Spanish doctorate holders differ across categories of some relevant variables. In this section we present some descriptive analyses linking the mobility experience with some factors of interest.

[3] The 2009 survey was done on a smaller sample.

Table 8.1 Variables and descriptive statistics

Quantitative variables	Mean	Standard error
Year of birth	1965	0.07
Time to PhD completion (months)	106	0.60
Time since PhD graduation (months)	124	0.87
Annual gross income (euro)	33,187	110.70

Categorical variables	%
Nationality	
Spanish (reference)	98.8
Foreign residents	0.4
Spanish and other nationality	0.8
Sex (men)	54.2
Marital status	
Married (reference)	65.1
Unmarried partner	3.8
Separated	1.5
Divorced	3.2
Widowed	0.6
Single	25.8
He/she has dependents (yes)	62.9
Exclusively basic or fundamental research during PhD (yes)	28.6
Exclusively applied research and/or experimental development during PhD (yes)	30.3
Main form of funding for doctoral studies	
Loans, personal savings and/or family support (reference)	16.7
Scholarship	42.0
Research assistantship	2.1
Teaching assistantship	8.8
Other full-time employment	22.0
Other part-time employment	3.8
Subsidized by employer	0.4
Other forms	4.2
Field of study	
Natural sciences (reference)	29.5
Engineering and agriculture	12.9
Medical sciences	22.7
Social sciences	21.0
Humanities	13.9
Sector of employment	
Industry/business (reference)	15.1
Government/public sector agency	34.5
Higher education	42.8
Private non-profit sector	4.0

(continued)

Table 8.1 (continued)

Categorical variables	%
No answer	3.6
Occupation in higher education (academic category)	
Full professor (reference)	1.4
Tenured professor	22.8
Lecturer (part time)	11.5
Other	6.4
No answer	57.9
Dedication to teaching (yes)	70.1
Permanency of present principal job (yes)	71.7
Working hours of present principal job	
Full-time (reference)	90.3
Part-time	6.1
No answer	3.6
Degree of relationship between his/her present principal job and his/her PhD	
High (reference)	58.5
Medium	21.1
Low	16.9
No answer	3.6
Postdoctoral as principal job (yes)	16.5
Researcher	
No (reference)	20.2
No, but investigated before	10.9
Yes	68.9
Formed a company (yes)	3.9
Supervission of a master or doctoral thesis (yes)	24.4
Cooperated with foreign research groups (yes)	37.0
Intention to move (yes)	7.5
Year PhD cohort	
1990–1997 (cohort 1) (reference)	34.1
1998–2002 (cohort 2)	33.6
2003–2006 (cohort 3)	32.3
International mobility experience (in the last 10 years) (yes)	17.3

N = 12,625 observations

Looking first at the international mobility experience by field of doctoral study we can observe in Fig. 8.1 that the natural sciences is the field with the highest level of such experience although variations across other fields are not very large, with the exception of the medical and health science. The low rate of international mobility among medical and health science researchers may be due to the fact that these researchers often follow a dual career track—also being employed in hospitals, with a long period of apprenticeship—which may give them less flexibility to move abroad for academic reasons.

Looking at some employment-related variables, the higher education sector appears to be the one where the level of international mobility is higher. This is

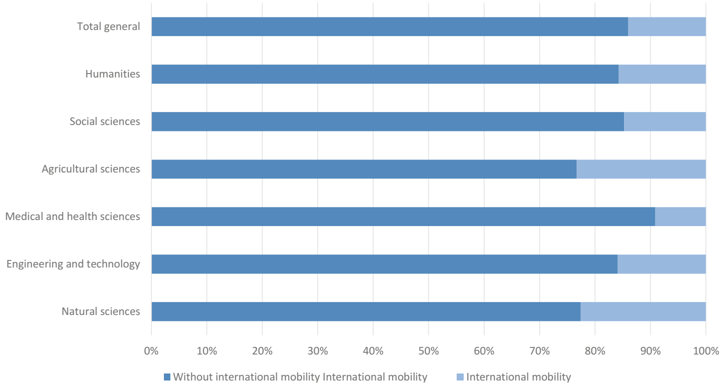

Fig. 8.1 International mobility experience by field of doctoral study. *Source*: Spanish CDH Survey 2006

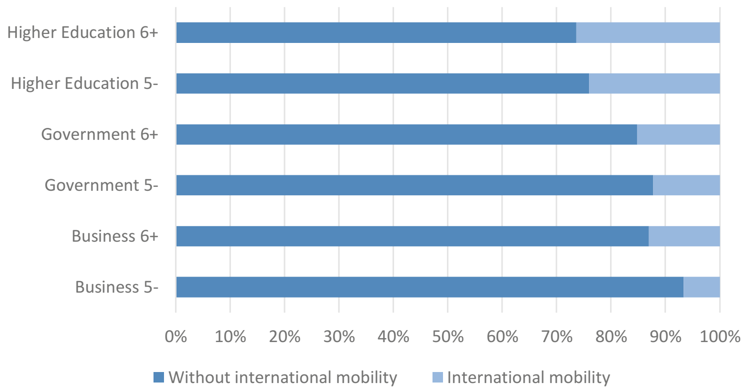

Fig. 8.2 International mobility experience by time since PhD graduation and sector of employment in 2006. *Source*: Spanish CDH Survey 2006

related to the fact that doctorate holders in this sector are more likely to work as researchers than those in other employment sectors (Fig. 8.2).

Relations between job stability and international mobility for Spanish doctorate holders are shown in Fig. 8.3 which shows that mobility levels among individuals with temporary positions are high in comparison to those with permanent ones. As part of the latter group may have been on a temporary contract at the time of mobility, one may infer that international mobility is more common among those with temporary contracts. It is interesting to note that even among recent graduates (denoted by “5-”) the international mobility levels of those in permanent positions are lower than the levels of those in temporary jobs.

The columns corresponding to those in a temporary or permanent position are divided into two groups. One has completed the PhD recently (-5) and the other has 6 years or more of professional experience.

The comparison between the levels of mobility between those engaged in research and non research jobs reveals the higher propensity of researchers to have been internationally mobile (Fig. 8.4).

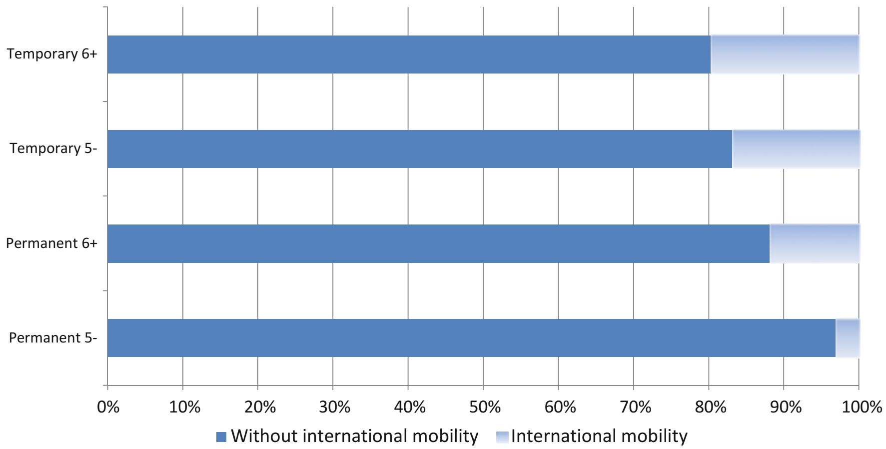

Fig. 8.3 International mobility experience by time since PhD graduation and type of employment in 2006. *Source*: Spanish CDH Survey 2006

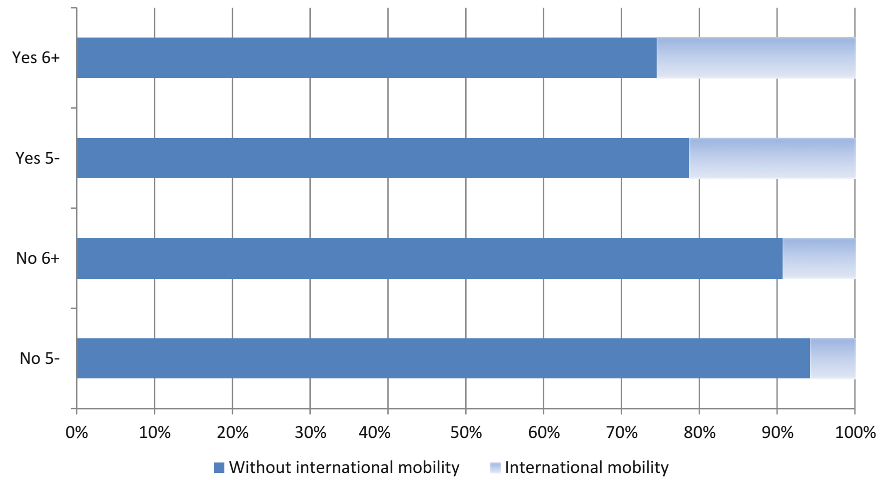

Fig. 8.4 International mobility experience by time since PhD graduation and engagement in research. *Source*: Spanish CDH Survey 2006

The left hand columns show respondents, with five or less, or more than 6 years of professional experience who are not (no) or who are (yes) engaged in research.

CDH data show that academic reasons are typically cited as the main reason for having gone abroad. However, there exists no direct question to identify the bottlenecks of international mobility in the present CDH model questionnaire, except for the motives to have moved out of and moved into the reporting country. The expectation is that family matters, especially having dependents, and affects the levels of international mobility. In Spain, the International mobility experience level of males is higher than that of female respondents (Fig. 8.5). Moreover,

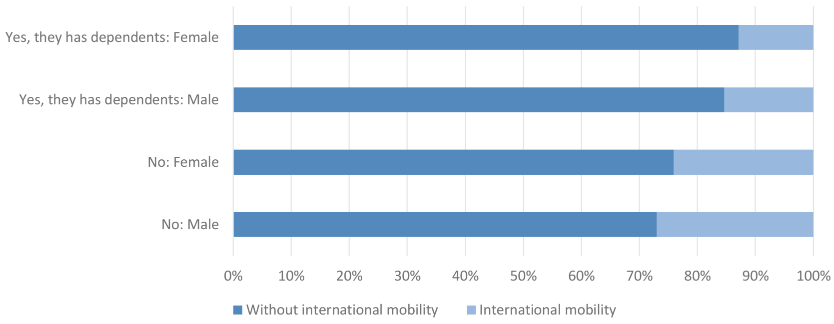

Fig. 8.5 International mobility experience by gender and dependents. *Source*: Spanish CDH Survey 2006

doctorates with dependents are less internationally mobile than those without. Although those who have dependents now may not have had them at the time at which they were mobile internationally, it remains safe to state on the basis of this data that mobility levels of those who do not have dependents are higher than the levels of those with dependents.

8.4.2 International Mobility Experience: Statistical Models

In order to account for the relative importance of several variables of interest net of the effect of other factors, we have used a binary logistic regression where our dependent variable Y_i is a dummy variable.

The first model, which results are presented in Fig. 8.6, considers international mobility as dependent variable: Y has a value of 1 if the respondent has had a post-doctoral stay abroad of more than 3 months in the past 10 years, and a value of 0 if the respondent has not had such a stay abroad. The model includes $x_1, x_2, \ldots, x_m$ explanatory variables (birth year, sex, field of PhD etc.).

Figure 8.7 explores for a smaller set of respondents whether they were still actively engaged in research or have abandoned research after their PhD. Figure 8.8 explores whether the respondent has obtained a permanent position. Figure 8.9 explores the stated intention to move in the following year.

The dependent variable Y_i conditioned on the explanatory variables $x_1, x_2, \ldots,$ x_m has a probability p_i of having as an outcome: 1 and $1 - p_i$ of having the outcome: 0.

Formula (1) provides the general logistic model:

$$\text{logit}\,(p_i) = \ln\left(\frac{p_i}{1 - p_i}\right) = \beta_0 + \beta_1 x_{1,j} + \cdots + \beta_m$$

To ease the interpretation of the models, Figs. 8.6, 8.7, 8.8 and 8.9 present the odds ratios instead of the regression coefficients (i.e. e^{β_j} instead of $\int$) (Mosteller

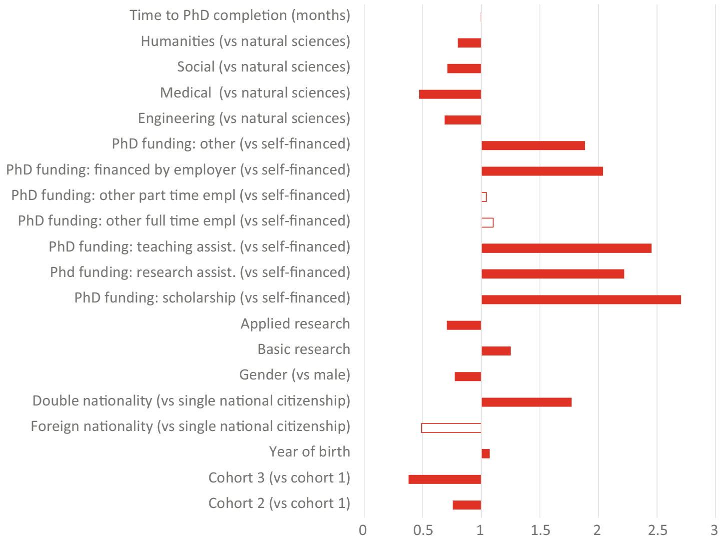

Fig. 8.6 Factors explaining the likelihood of international mobility

1968). The standard errors and confidence intervals are also transformed in this way. To further facilitate interpretation we have subtracted "1" from the odds ratio, so that the effect of a change in the value of a variable is immediately clear. For example, in the case of Fig. 8.6, the odds ratio is the ratio of respondents with international mobility experience of the exposed group (the interest category of the independent variable: e.g. those having the "female" gender) and those with international mobility experience in the unexposed group (the reference category, e.g. those having the "male" gender). i.e. in the figure female researchers are 23 % (significantly) less likely to have international mobility experience than their male counterparts. Whereas those who "have received a government scholarship for the funding of their PhD", are 150 % more likely to have international mobility experience.

We begin with the analysis of the factors associated to past postdoctoral international mobility. The effect of individual characteristics (age, cohort, sex and nationality) have been studied as well as the effect of some trajectory variables such as those related to field and type of research, source of funding for the PhD or time elapsed from the granting of the bachelor to the PhD degree. The model has nine significant variables and it is illustrated by Fig. 8.6.

Figure 8.6 presents the results of a logistic regression model, depicted as odds ratio minus 1. The Pseudo R-Square is 0.14, N = 12,625. Significant variables are depicted as solid bars. Non significant variables are depicted as white bars.

As we can observe, age is significantly related to past mobility experience: in each cohort the younger respondents are more likely to have had international

Fig. 8.7 Continuing doing research or having abandoned

mobility experience in the past 10 years. Those in cohort 3 are least mobile followed by those in cohort 2 and finally cohort 1. Those in cohort 3 are less likely to have had international mobility experience. They also had less time to accumulate International mobility experience. This, however, does not explain the lower rate of mobility of cohort 2 in comparison to cohort 1. It thus appears as if the more senior respondents (in cohort 1) are those who have highest levels of mobility in Spain.[4]

[4] The potential explanation could be related with 3 different factors: (a) effective behavior: people have international mobility after they get a permanent position; meaning older people have more mobility; (b) historical factors: the older generations had more opportunities for international mobility because in the nineties there were more resources for less people than later on; (c) bias in retrospective answers: older people in fact do not respond properly to the time horizon of the answer (international mobility experience 1996–2006) and they merge all life experiences.

Fig. 8.8 Likelihood of having a permanent position at the time of the survey

Those with double nationality (who tend to be from Latin America) tend to have higher levels of international mobility.[5] Since respondents with double passports are more likely to have engaged in pre-doctoral mobility (at least in the case of Latin American PhD holders in Spain), their higher levels of postdoctoral international mobility provide a reason for considering pre-doctoral mobility in subsequent studies. Pre-doctoral mobility experience (including e.g. participation in the Erasmus program) may influence the propensity for post-doctoral mobility.

Female doctorate holders show lower levels of international mobility. Natural scientists show the highest levels of international mobility. Likewise, those in basic research show higher levels of international mobility, whereas those in applied

[5] Note that in the definition of postdoctoral international mobility only mobility for professional reasons was included.

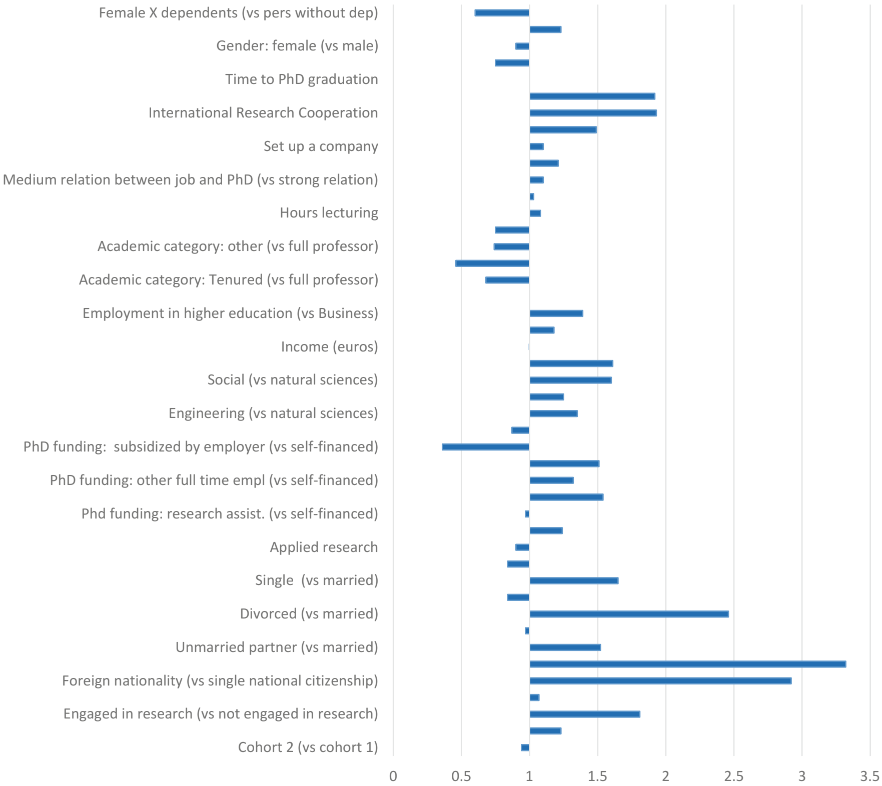

Fig. 8.9 Intention to move out of the country in the coming year

research show significantly lower levels. One may hypothesise that this is because basic research fields in general are more internationalised and that research can be done either irrespective of location or to be sometimes dependent on the availability of specific research infrastructures which require international mobility. Applied research may often be more location specific.[6]

[6] There may be a correlation between whether or not respondents were engaged in applied and basic research and the fields in which they did their doctorate (e.g. engineers are probably more likely to be engaged in applied research than natural scientists). Since both "applied" and the non natural science doctorate fields have a negative effect on the propensity for international mobility, the sign of the variables is not likely to be affected by this interaction. When this was explored in more depth the following was found: those in the natural sciences were indeed more likely to be engaged in fundamental research than respondents in any of the other categories. Furthermore, for all categories those engaged in basic research were more likely to have international mobility experience than those who were not exclusively engaged in fundamental research.

Doctorate holders who funded their doctoral research through research related activities (either grant or fellowship holders, teaching assistants, research assistants) have been more mobile than those who were self-financed or financed through loans. This may be because they could devote more time to developing their research, but an alternative explanation is that there is a selection effect and that those who were "successful" in getting a grant or be otherwise competitively selected to be engaged in research related activities are those with the highest potential to be successful in research; have greater potential in receiving new grants (including for international mobility) and therefore to be the most likely to have international mobility experience after their PhD as well (which appears strongly associated with the research career).

The more time has elapsed between the bachelor degree and the obtaining of the doctorate, the less likely respondents are to have international postdoctoral mobility experience. The effect appears rather small.[7] This is a complex variable which can be related to many different factors for which it is not possible to control in this model (among them dependents or main occupation at the time of doing the PhD or obtaining additional qualifications such as Masters after the Bachelor degree). It is therefore difficult to draw even preliminary conclusions from it.

A few interpretations of the Fig. 8.6 can be given as examples.

- Female respondents have a 23 % lower probability to have postdoctoral international mobility experience than male respondents.
- Respondents who exclusively did basic research in their doctorate are 25 % more likely to have international mobility experience than those who did not dedicate themselves exclusively to this pursuit whereas those exclusively engaged in applied research are significantly less likely to have international mobility experience .
- Respondents whose PhD was financed through a scholarship are 2.7 times more likely to have international mobility experience than those who were self-financed or financed their PhD with loans or family support.

Secondly, this study has explored the relative effect of international mobility on the type of occupation (research versus non research) (Fig. 8.7) and on career advancement on the form of access to a permanent job (Fig. 8.8). In these models international mobility is regarded as an independent or explanatory variable.

Fig. 8.7 shows the results of a regression model which compares the group of PhD holders who were still in research (at the time of the survey) with those who had abandoned research since their doctorate. In this model one group of respondents was excluded because they, paradoxically for PhD holders, indicated

[7] It is important to acknowledge that this is a continuous variable and the difference between those who have completed their doctorate quickly and those who have taken more time can be a large number of months e.g. if the difference is over 30 months in duration, the effect would be around 2.5 %.

that they had never been engaged in research. Looking at the results, it is interesting to note that those in the most recent cohort are significantly more likely to have abandoned research. This may be due to the expansion of doctoral training in Spain in the past decade: the amount of research positions available may not have kept pace. Those who financed their doctorate through being a research assistant or through other full time employment are significantly more likely to have abandoned research. Female doctorate holders are significantly more likely to have abandoned research. Doctorate holders who did their PhD in the medical sciences or social sciences are significantly more likely to have abandoned research than those in the natural sciences. There are no significant differences between those in the natural sciences and the humanities or engineering in this respect. Doctorate holders working in the business sector are significantly more likely to have abandoned research in comparison to any of the other sectors. Those with international mobility experience after their doctorate are significantly more likely to continue to be in research. Those who have had a contract as a postdoctoral fellow are significantly more likely to have remained in research at the time of the survey.

Fig. 8.7 presents the results of a logistic regression model, depicted as odds ratio minus 1. The Pseudo R-Square is 0.254, N = 9,852. Significant variables are depicted as solid bars. Non significant variables are depicted as white bars.

We now turn to the analysis of career advancement as measured by the access to a permanent position (Fig. 8.8); our results show that the young and those who have recently graduated as PhDs are less likely to have permanent employment (i.e. they are in temporary positions). There is no significant effect of gender when one considers the whole sample. However additional analyses were performed on the separate cohorts in which a significant negative effect of being female in the more recent cohort (3) was found. Since this is no longer visible in the two older cohorts, one may conjecture that the negative bias on full-time employment of female researchers disappears with time.

As observable in Fig. 8.8, in comparison to natural scientists, doctorate holders in all other fields are more likely to have obtained a permanent position at the time of the survey. The exception to this is the group of doctorate holders in the medical sciences. Taking the private sector as the reference, respondents in other sectors are less likely to have a permanent position than those in the private sector. International cooperation (in the 2 years preceding the survey) appears to be negatively related to being in a permanent job. This appears counter-intuitive. A potential explanation is that it may especially be domestic networks that influence career progression in the Spanish national context (Zinovyeva and Bagues 2010). If this is the case, a possible justification for this effect might be that energy devoted to international collaboration (in the pre-2006 context) could not be invested in the development of local networks which might help explain the observed negative "effect". An alternative explanation for this observed "effect", however, is that those in temporary positions are more inclined to engage in international collaboration than those who already have a permanent position. Since the variable only accounts for international collaboration in the 2 years preceding the survey it is likely that a considerable share of the respondents with permanent positions already had these positions during the period in which this variable was measured. The negative association of international collaboration with having a permanent position may therefore itself be more a consequence than a cause.

The most striking result is the significant negative effect of international mobility experience on the likelihood of having obtained a permanent position: those who have international mobility experience are 38 % less likely to have a fixed position (controlled for by the other variables).

Finally, in Fig. 8.9, the analysis addresses the determinants of the intention to move internationally in the next year looking again at a number of individual and career/trajectory variables.

Figure 8.8 presents the results of a logistic regression model, depicted as odds ratio minus 1. The Pseudo R-Square is 0.372, N = 11,712. Significant variables are depicted as solid bars. Non significant variables are depicted as white bars.

Figure 8.9 presents the results of a logistic regression model, depicted as odds ratio minus 1. The Pseudo R-Square is 0.13, N = 11,192. Significant variables are depicted as solid bars. Non significant variables are depicted as white bars.

The results in Fig. 8.9 show that those who are more likely to have the intention to move in the near future are those who are engaged in research, those who are younger, foreigners or those with double nationality, as well as those with a lower degree of legal ties to a partner. As regards career and trajectory variables, the intention to move abroad in the near future is more likely among those who were not engaged exclusively in basic research during their doctorate, those in fields other than the natural sciences,[8] those with lower earnings,[9] those in a non-permanent position at universities (contracted lecturer etc), those who have supervised PhD theses, those who have cooperated with foreign research groups and those who already have postdoctoral international mobility experience in the preceding 10 years. In isolation the variable "dependents" does not have a significant effect. Female doctorate holders are less likely to have the intention to move than their male counterparts. However female respondents with dependents are significantly less likely to have the intention to move than all other respondents and when this variable is included there is no significant difference between male and female respondents.

[8] It is not immediately clear why the probability of those who were exclusively engaged in basic research during their PhD and/or of natural scientists to have international mobility experience, is relatively high, while the probability of the same groups to have the intention to move is relatively low. One potential explanation is that natural scientists have relatively high rates of mobility early on in their career, while social scientists and those in the humanities have relatively higher rates of mobility at a later stage in their career. The relationship between age group, mobility and field was explored to see if this holds. Natural scientists consistently have higher mobility. There are no clear differences between the fields in the levels of mobility per age group.

[9] The effect of earnings appears very low, but one has to realise that the variation of this variable, which is measured in euro, is quite large.

8.5 Conclusions and Policy Implications

In this chapter we have presented a national case study of the CDH survey in Spain with a focus on international mobility from different angles. We have explored the factors associated with the likelihood of Spanish doctorate holders to have been engaged in international mobility in the past and with the intention to move in the future. We have also analysed the role of international mobility (along with other factors) in two relevant aspects of the career: the probability of being in a research job and the likelihood of holding a permanent position.

Our findings show that female PhDs in Spain are considerably less likely to have international mobility experience than their male counterparts. Moreover Spanish female doctorate holders with dependents are significantly less likely to have international mobility experience than either their female peers without dependents or their male counterparts. Also in designing policies to promote international mobility, it is important to recognise that people in different stages of their life either have less or more possibilities/interest to be move abroad.

In line with previous studies, our results also reveal that past and future mobility are connected and previous mobility experience makes it more likely that doctorate holders will intend to move abroad in the future. Therefore policies aiming to foster mobility throughout the career should take the effects of previous mobility into account. This supports the importance of early career mobility programs. Probably, though this was not studied in this project, pre-doctoral mobility has a similar positive effect on future mobility.

The literature and policy debates highlight several positive impacts of doctorate holders' mobility. One of which, the relationship between international mobility and international collaboration is supported by the analysis presented here. Additionally, international mobile doctorate holders are more likely to continue to be engaged in research at the time of the survey than their non mobile counterparts. However, while international mobility may have positive effects on the functioning of research and innovation systems through knowledge diffusion, international collaboration etc., it is less clear that it has a positive effect on the individual careers of doctorate holders in all academic systems. In fact those with international mobility were found to be less likely to have obtained a permanent position in Spain. Recruitment and promotion systems may need to be adjusted to achieve an optimal balance between mobility and retention if it indeed has positive systemic effects. There is no significant effect of gender on progression towards a permanent position. This bias is visible, however, in the most recent cohort. In the older cohorts this effect has disappeared and we may conjecture that the negative bias on full time employment of female researchers disappears with time.

The proportion of PhDs working as researchers can be a potential indicator of the returns of the PhD training investments into the R&D system. In this regard, doctorate holders in the private sector are significantly more likely not to be engaged in research at the time of the survey. Two considerations are worth mentioning here; firstly, apparently (some) doctorate holders have skills that are considered relevant in non-research positions in the private sector; secondly, part of the argument for an increase in the number of PhDs (in society as well as in the private sector) over the past decades is the supposed positive effect on innovative capabilities.

The results presented in this chapter show the potential of CDH data to inform policies on the labor market and career of doctorate holders. A suggestion for further research is to explore to what extent doctorate holders in non-research positions nonetheless contribute to the innovation, and other forms of, performance of companies. In any case, international mobility experience was found to be positively related to the likelihood of PhDs to have remained in research.

The analysis of 2006 survey data are presented in this chapter at a moment where an economic crisis and subsequent major cuts in the Spanish research budget have dramatically altered the situation in the Spanish research system, can serve as a reference for future studies aiming to assess the effect of these developments on internationally mobility in Spanish academe. Anecdotal evidence and individual reports indicate that outbound mobility in recent years has been considerable.

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References

Ackers L (2005) Moving people and knowledge: scientific mobility in the European Union. Int Migr 43(5):99–131

Ackers L (2008) Internationalisation, mobility and metrics: a new form of indirect discrimination? Minerva 46(4):411–435

Auriol L, Felix B, Schaaper M (2010) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators—2nd edn—The OECD/UNESCO Institute for Statistics/Eurostat Careers of Doctorate Holders Project. OECD Science, Technology and Industry working papers 2010/01. OECD Publishing, Paris. http://dx.doi.org/10.1787/5kmlfbn2ddtd-en

Auriol L, Misu M, Freeman RA (2013) Careers of doctorate holders: analysis of labour market and mobility indicators. OECD Science, Technology and Industry working papers 2013/04. OECD Publishing, Paris

Bozeman B, Corley E (2004) Scientists' collaboration strategies: implications for scientific and technical human capital. Res Policy 33:599–616

Cañibano C, Otamendi J, Andújar I (2008) Measuring and assessing researcher mobility from CV analysis: the case of the Ramón y Cajal programme in Spain. Res Eval 17(1):17–31

Cañibano C, Otamendi FJ, Solís F (2011) International temporary mobility of researchers: a cross-discipline study. Scientometrics 89(2):653–675

Cruz-Castro L, Sanz-Menéndez L (2010) Mobility versus job stability: assessing tenure and productivity outcomes. Res Policy 39(1):27–38

De Filippo D, Sanz E, Gómez I (2009) Quantitative and qualitative approaches to the study of mobility and scientific performance: a case study of a Spanish university. Res Eval 18 (3):191–200

Defazio D, Lockett A, Wright M (2009) Funding incentives, collaborative dynamics and scientific productivity: evidence from the EU framework programme. Res Policy 38:293–305

EC (2000) Communication from the Commission to the Council, the European Parliament, The Economic and Social Committee and The Committee of the Regions—towards a European Research Area, COM(2000)0006 final. Retrieved from http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=en&type_doc=COMfinal&an_doc=2000&nu_doc=6

EC (2001a) Communication from the Commission to the Council and the Parliament: a mobility strategy for the ERA, COM(2001)331 final. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2001:0331:FIN:EN:PDF READ

EC (2001b) High level expert group on improving mobility of researchers: final report. European Commission (DG Research), Brussels

EC (2005) The European charter for researchers—the code of conduct for the recruitment of researchers. European Commission (DG Research), Luxembourg: Office for Official Publications of the European Communities. Retrieved from http://ec.europa.eu/eracareers/pdf/am509774CEE_EN_E4.pdf

EC (2007) The European research area, new perspectives, inventing our future together, green paper 04.04.2007. http://ec.europa.eu/research/era/pdf/era-greenpaper_en.pdf

EC (2011) Horizon 2020: Commission proposes €80 billion investment in research and innovation, to boost growth and jobs, IP/11/1475, 30/11/201. Retrieved from http://europa.eu/rapid/press-release_IP-11-1475_en.htm?locale=fr

EC (2012a) Communication from the European Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: Horizon 2020—The Framework Programme for Research and Innovation, COM(2011) 808 final. Retrieved from http://ec.europa.eu/research/horizon2020/pdf/proposals/communication_from_the_commission_-_horizon_2020_the_framework_programme_for_research_and_innovation.pdf#view=fit&pagemode=none

EC (2012b) Marie Curie actions—research fellowship programme. Retrieved from http://ec.europa.eu/research/mariecurieactions/index_en.htm

Edler J, Fier H, Grimpe C (2011) International scientist mobility and the locus of knowledge and technology transfer. Res Policy 40(6):791–805

Enders J, Musselin C (2008) Back to the future? The academic professions in the 21st century. In OECD higher education to 2030, vol 1: Demography, chapter 4. Retrieved from: http://www.oecd.org/edu/ceri/41939654.pdf

Ferro A (2006) Desired mobility or satisfied immobility? Migratory aspirations among knowledge workers. J Educ Work 19(2):171–200

Fontes M (2007) Scientific mobility policies: how Portuguese scientists envisage the return home. Sci Public Policy 34(4):284–298

IDEA Consult, NIFU STEP, WIFO, LOGOTECH, The University of Manchester (2010) MORE study on mobility patterns and career paths of researchers. Final report, Brussels. Retrieved from: http://ec.europa.eu/euraxess/pdf/research_policies/MORE_final_report_final_version.pdf

Jonkers K (2011) Mobility, productivity, gender and career development of Argentinean life scientists. Res Eval 20:411–421

Jonkers K, Cruz-Castro L (2013) Research upon return: the effect of international mobility on scientific ties, production and impact. Res Policy 42(8):1366–1377

Jonkers K, Tijssen R (2008) Chinese researchers returning home: impacts of international mobility on research collaboration and scientific productivity. Scientometrics 77(2):309–333

Jöns H (2007) Transnational mobility and the spaces of knowledge production: a comparison of global patterns, motivations and collaborations in different academic fields. Soc Geogr 2:97–114

Leyman A, Jidkova S, De Grande H, Van der Goten G, Van Rossem R, Vandevelde K (2009) Resultaten van de 'survey of junior researchers' aan de UGent, ECOOM expertisecentrum onderzoek en ontwikkelingsmonitor. Universiteit Gent, Gent, Retrieved from https://biblio.ugent.be/input/download?func=downloadFile&recordOId=674598&fileOId=1100728

Melkers J, Kiopa A (2010) The social capital of global ties in science: the added value of international collaboration. Rev Policy Res 27:389–414

Morano-Foadi S (2005) Scientific mobility, career progression, and excellence in the European research area. Int Migr 43(5):133–162

Mosteller F (1968) Association and estimation in contingency tables. J Am Stat Assoc 63 (321):1–28

Ponomariov BL, Boardman PC (2010) Influencing scientists' collaboration and productivity patterns through new institutions: university research centers and scientific and technical human capital. Res Policy 39:613–624

Sanz-Menéndez L, Cruz-Castro L, Alva K (2013) Time to tenure in Spanish universities: an event history analysis. PLoS ONE 8(10):e77028. doi:10.1371/journal.pone.0077028

Vandevelde K (2011) Mobiel en daarom excellent of excellent en daarom mobiel? Thema 2011:3

Zinovyeva N, Bagues M (2010) Does gender matter for academic promotion? Evidence from a randomized natural experiment. FEDEA documentos de trabajo. Available: http://www.fedea.es/pub/Papers/2010/dt2010-15.pdf. Accessed 11 Nov 2012

Determinant of Careers Patterns for Doctorate Holders

9

Joana Duarte and Joana Mendonça

9.1 Introduction

Science is crucial for social and economic development and universities have been the prime place for developing science, whether it is for research training or for scientific production (Heitor et al. 2013). Universities have been recognized as central to social and economic achievements within a nation (Neumann and Tan 2011), as they provide the training of human resources crucial to build a knowledge-based society. The growing awareness of the importance of human resources in science and technology led countries to invest heavily in their training, namely at a doctoral level (Recotillet 2003). This building process is a cumulative one and has been particularly intense in countries willing to catch up in technological terms (Fontes 2004).

In a knowledge-based economy, research training is more important in order to effectively combine highly specialized research and industrial and economic capacity (Neumann and Tan 2011). However, the way training conditions occur depends on the national context and on the specific mechanisms that are created to surpass national constraints. In this context, science policies are essential mechanisms for this process of building advanced human capital, which requires stable public strategy overtime, together with adaptable and resilient research institutions (Heitor et al. 2013). Countries can choose a model based on public policies where the responsibility is centred on government or a model where responsibility lies in the business enterprises and then decide what the role is of the government/firms in the doctoral and post-doctoral training, or mixed models changing over time.

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Independently of this choice, growing literature suggests that the time when a doctoral degree almost automatically leads to a long lasting academic career is over and researchers increasingly find themselves competing for jobs in the non-academic labor market (Levecque et al. 2013). Consequently, the current challenge is to adjust advanced training to the requirements of a wider variety of careers (European Commission 2003), leading several countries and institutions to find new ways of organizing doctoral research and training (Thune 2009), addressing the skills doctorates need to work in a non-academic position.

In its origins, the doctorate was seen as a proof of one's ability to teach inspired by the Humboldtian idea of the university as place where research is unified (Probst and Lepori 2008). Although a doctorate is still often seen as an apprenticeship in which students learn through direct collaboration with a professor, nowadays, a doctorate is seen as a *rite de passage* (Probst and Lepori 2008) where a post-doctoral position occupies a specific training position for the labor market. Some believe that scientific training endows the individuals with a tacit ability to acquire and use knowledge and apply it in new ways, which may generate a particular attitude of the mind that can be an important contribution to innovative activities (Senker 1995). So a doctorate is not an intensive study in a specific field of science but it is a process of socialization and learning-by-doing in an academic community, where students learn how to carry out original research (Probst and Lepori 2008). This process is not static, but is dynamic and has been changing through the years as "the conception and the practices of the doctorate have increasingly been put under pressure by a series of deep changes both in higher education system and in its wider socio-economic landscape" (Enders 2004). These changes raise new challenges for the universities in their third mission of promoting linkages and knowledge transfer to the economy and the society, meaning that research can no longer be focused solely on the development of basic research and on the reproduction of academic practices (Probst and Lepori 2008). Doctoral training is essential for R&D and innovations systems development, but is not enough to educate doctorates, it is also important that they go into the labor market as a way of giving the contribution of their training back to society. Universities provide training and research and firms establish a bridge with the economy. In this context, doctorate students are highly important in the university-firm relationships, since they are significant producers of knowledge in collaborative research projects and are important channels for knowledge transfer between universities and firms (Thune 2009).

This paper presents an analysis of the evolution of doctoral careers looking at the Portuguese case, making use of the Careers of Doctorate Holders (CDH-2009 Survey) results, and compares Portugal with three other countries: Belgium, Denmark and Spain, chosen due their similarities in size or in culture. We use logistic regressions to identify determinants for different career patterns for doctorates, and an earnings equation to access the differentiation of doctorate earnings in these countries. Our results point to differences of patterns in different countries.

The remainder of this chapter is divided in four parts, as follows. After this introduction, the next section presents an outline of the Portuguese case, focusing in on the evolution of the doctoral training and careers. The section three that follows presents the results of CDH-2009, and an overview of the dimensions used for our analysis. Section four presents our results on the determinants of career paths and mobility, followed by a section with the conclusions.

9.2 Doctoral Training and Doctoral Employment: The Portuguese Case

In Portugal the training of the working population has evolved in the last four decades, accompanied by the legal reform of tertiary education system and a significant increase in public investment in science and technology (Heitor et al. 2013). Due to this investment, there was a significant increase in the generation of qualified human resources, and in the capacity to train individuals at the doctoral level.

Figure 9.1 shows the evolution of doctoral degrees obtained in Portugal from 1970, distinguishing between those awarded in Portugal and those obtained abroad and recognized in Portugal. In the 1970s, the major part of Portuguese doctorate holders were trained abroad, a reality that started to change in 1984. After this decade, the number of doctoral degrees awarded started increasing exponentially leading to a steady rate of 1,500 per year after 2009. In 2009, there were 22,000 doctorates in Portugal, who had obtained their degrees in Portugal and in many other countries.

Until the late 1970s doctoral degrees were only be awarded by the four oldest universities—Coimbra, Lisbon, Porto, and the Technical University of Lisbon—even though the universities created in the early 1970s were also entitled to do so (Heitor et al. 2013). In Fig. 9.2, we present the evolution of doctoral degrees obtained and recognized by Portuguese universities by decade, and show that in

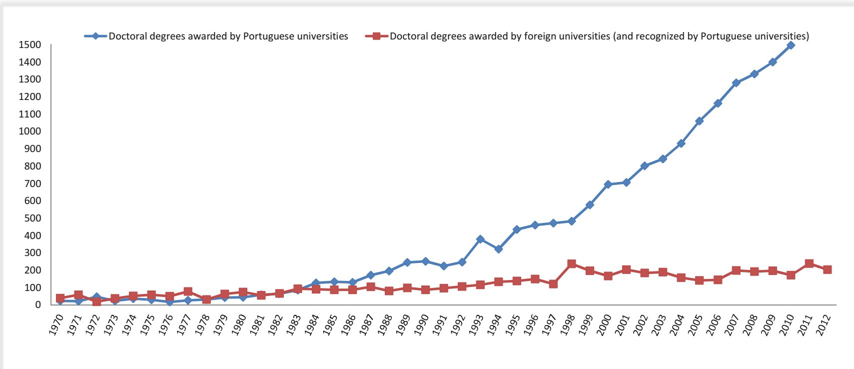

Fig. 9.1 Evolution of doctoral degrees obtained in Portuguese universities and abroad, 1970–2012. *Source*: DGEEC/MEC, RENATES: 1970–2012

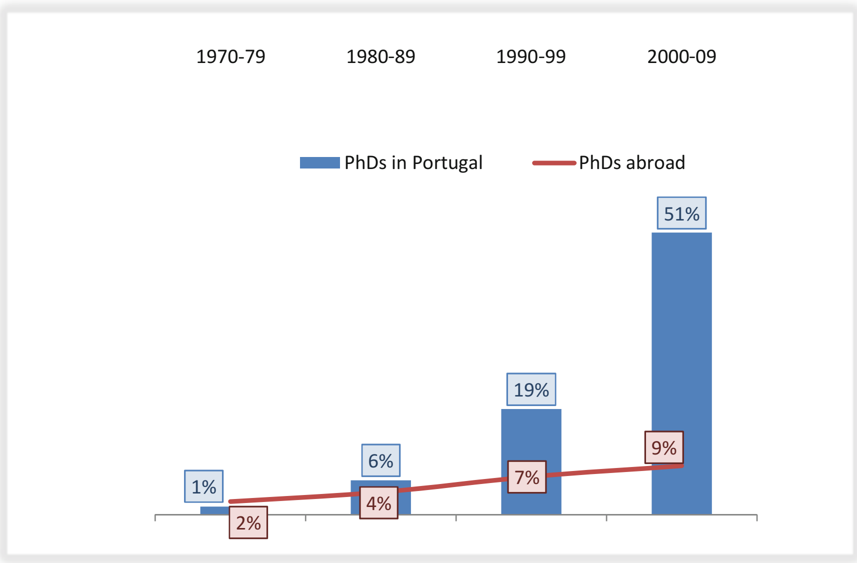

Fig. 9.2 Evolution of doctoral degrees obtained or recognized by Portuguese universities by decade, 1970–2009. *Source*: DGEEC/MEC, RENATES: 1970–2009

the first decade, the majority of doctoral degrees were obtained at foreign universities (62 %) while in the second decade 60 % of the doctorates started to be awarded at Portuguese universities. In the last two decades, the proportion of doctoral degrees obtained abroad decreased by 26 % and 15 %, respectively. This inversion follows the ability for Portuguese universities to train their doctorate candidates, as a result of the increase in the maturity of universities and research systems.

This inversion was supported with different funding mechanisms: the training of doctorates abroad was funded by a grant system, followed by the promotion of doctoral and postdoctoral grants in Portugal and abroad to reinforce the investment in highly skilled human capital. In other words, in the early 1970s and 1980s the effort was to internalize the training capacity in the country was followed by an effort to consolidate this investment in the following decades (Heitor et al. 2013). The investment had, as a consequence, a significant increase of doctorate holders at the Portuguese higher education institutions. In Table 9.1, we observe the evolution of doctorate holders in the Portuguese higher education system, where this growth is visible.

In Fig. 9.3, we present the distribution of doctorates per sector for Portugal, Belgium, Denmark, and Spain. The higher education sector is the major employer in Portugal, and it has not reached the level of other countries, and it is showing some capacity to absorb the graduate doctorates. Consequently, doctorate holders in Portugal are mostly concentrated in one sector, higher education (85 %), and the

Table 9.1 Evolution of the percentage of doctorate holders in the total higher education sector (HES) teaching staff, 2001–2012

Year of reference	Number of total doctorate holders in HES teaching staff	Percentage of doctorate holders in total HES teaching staff
2001	9,465	26.5
2002	10,173	28.1
2003	10,657	29.3
2004	11,311	30.8
2005	12,090	32.3
2006	12,639	35.0
2007	13,374	38.0
2008	14,205	40.1
2009	15,563	43.0
2010	16,771	44.1
2011	17,247	46.5
2012	17,620	49.7

Source: DGEEC/MEC, REBIDES 2001–2012

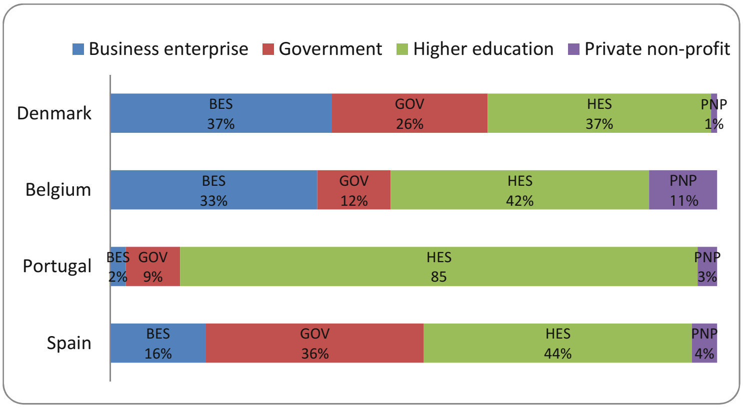

Fig. 9.3 Doctorate holders by country and sector of employment, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

presence of doctorate holders is less representative in the business enterprise sector. In Belgium and Denmark, doctorate holders are more evenly distributed within the sectors of employment, with a higher percentage of doctorate holders in the higher education sector (40 % and 30 %, respectively) but also in business enterprise sector (37 % and 32 %, respectively). In the case of Spain, doctorates are mostly concentrated in both higher education and government sectors (43 % and 38 %, respectively).

The number of doctorates is related to the intensity of R&D activity and in Fig. 9.4 we observe the evolution of business enterprise R&D expenditure (BERD)

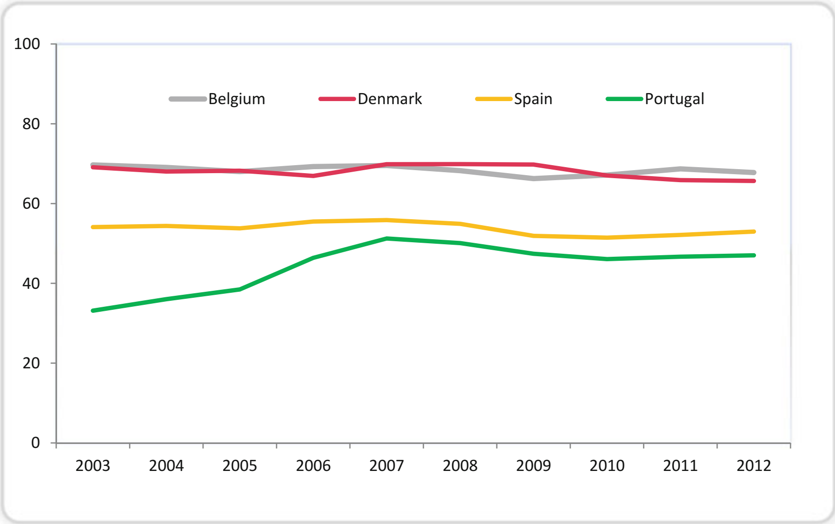

Fig. 9.4 Percentage of business enterprise sector intramural expenditure in total R&D expenditure by country, 2003–2012. *Source*: Eurostat—Research and Development Statistics

in the four countries. In Portugal, there was a recent increase in the business expenditure in R&D, which reached 50 % in 2007, while in Spain it was 54 %, 69 % in Denmark and 70 % in Belgium.

This increase led to a rise in the demand for doctorates in the business sector, and created more opportunities in the labor market. Figure 9.5 shows that employment patterns are changing for recent graduates (those who obtained their degree between 2008 and 2009). Even though the higher education sector is the first employer for doctorates, we observe that for recent graduates, the number of individuals employed at higher education institutions is decreasing (78 % against 87 %), while it is increasing in government, business enterprises and in private non-profit institutions (1 %), with the highest growth in the government and business sectors.

A study done for Portugal in 2004 pointed out the reasons for the absence of doctorate holders in the business enterprise sector, despite the creation of policy programs giving support to firms in Portugal that hire Master's and doctoral graduates (Fontes 2004). Fontes interviewed employers and employees in the business sector to identify the factors affecting the decision to employ doctorate holders and the motivations for individuals to pursue a career path in private firms, showing that a major part of Portuguese firms lacked qualified personnel. This lack of qualified personal is seen as one of the major barriers to innovation, and it influences the firms' capacity to absorb external information, and prevents firms from understanding the benefits of employing doctorate holders.

Ferreira and Otley (2005) demonstrates the importance of having qualified personnel in firms, arguing that firms' management misunderstand the real value and

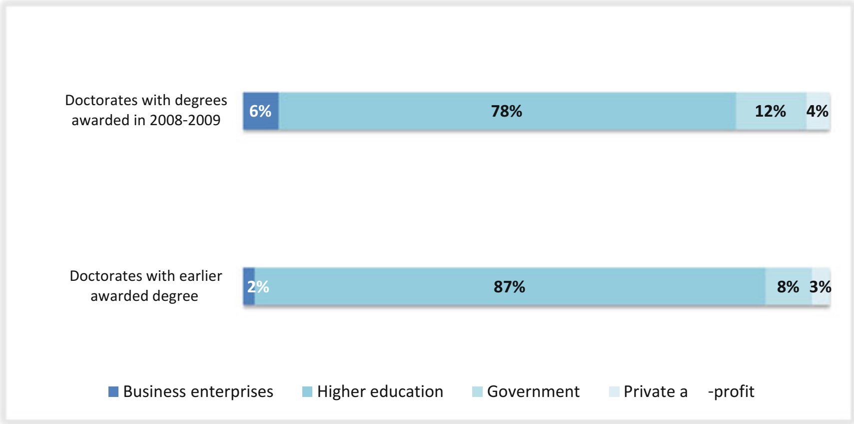

Fig. 9.5 Employment patterns of former doctorates vs. recent doctorates in Portugal, 2009. *Source*: DGEEC/MEC, CDH-2009

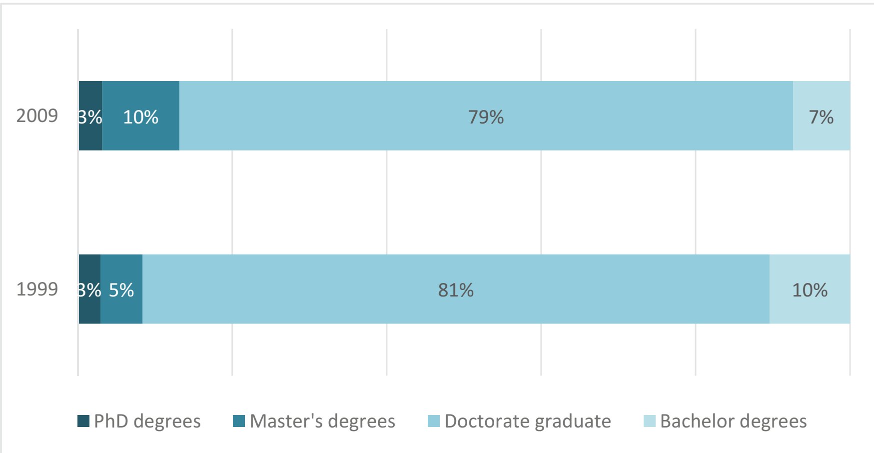

Fig. 9.6 Researchers in business enterprise sector by academic degree (FTE), 1999–2009. *Source*: DGEEC/MEC, R&D Survey 1999–2009

contribution of more qualified employees. Fontes (2004) described some reasons to explain the lack of doctorates and other graduate degree holders in Portuguese firms at that time. The first reason was that some firms were in a certain stage of development where they did not really need personnel with such a high qualifications, and they would benefit more by recruiting graduates (ISCED 5B level) (Fontes et al. 2004). This explanation shows one of the factors that explain the low percentage of people devoted to R&D activities in firms. Figure 9.6 shows the distribution of researchers per academic degree in the last decade, illustrating that firms have mainly an ISCED 5B employment pattern, having had a significant increase in the number of master's degree holders, which has doubled in the last 10 years.

Additional reasons named to explain the small numbers of doctorates in the business sector were the lack of economic resources to hire them in a full-time position, a lack of understanding about the potential usefulness of these professionals for the firm and difficulties in clearly identifying the type of qualifications needed. Nevertheless, some new technology-based firms also stated their need concerning postgraduate competencies and pointed to having difficulties in attracting and retaining these human resources due to scarce resources. From the post graduates side, they demonstrate some reluctance to work in firms because they have a genuine desire to pursue a scientific career and some of them are accused of considering a contribution to the advancement of knowledge to be more important to them than the organization's objectives. In addition, doctorate holders show preference for firms with R&D activities and with a good scientific reputation (Jones 1992). Although R&D investments by firms in Portugal have increased since 2004 (see Fig. 9.4), 53 % of BERD major investment was concentrated at five firms. The firm with the highest R&D expenditures in 2012 was a telecommunications firm (Grupo Portugal Telecom) which had R&D expenditures of 145,000 euros and 367.9 total personnel in full-time equivalent (FTE),[1] of which 4.6 are doctorate holders in FTE. The second firm with the highest R&D expenditures in 2011 was BIAL, a pharmaceutical firm with 55,500 euros in R&D expenditure and a total of 76.3 R&D personnel in FTE, of which 20.1 are doctorate holders. In Table 9.2 we present 29 firms[2] out of 100 with more R&D expenditures in 2011, which declared that doctorate holders at their firms dedicated at least 10 % of their time to R&D activities. What we can observe is the low number of doctorate holders devoted to R&D activities in firms. This number is only of some significance in pharmaceutical and biotech companies, and in ISQ (Instituto de Soldadura e Qualidade), which focused on metrology.

These numbers show that despite the significant increase of R&D investment in the business sector, the share of doctorate holders has not yet reached a similar level. Nevertheless, highly skilled human resources are slowly growing in the

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[1] We follow the defitnition in the Frascati Manual, «One full time equivalent (FTE) is thought as one person year. Thus, a person who normally spends 30 % of his/her time in R&D and the rest on other activities should be considered as 0.3 FTE» (2002: 99).

[2] From the total 100 firms with more R&D expenditure in 2012, only 29 firms authorized the publication of information about doctorate holders in FTE. From the remaining 71 firms, 22 did not have doctorate holders performing R&D, 14 did not authorize the publication of this information and 35 did not authorize the publication of any data. For more detailed information please check: http://www.dgeec.mec.pt/np4/206/%7B$clientServletPath%7D/?newsId=11&fileName=Ranking2012_PublicacaoEmpresas_022015.pdf

Table 9.2 Business enterprises with increased R&D expenditure, 2012

Business enterprises with increased R&D expenditure in 2012					
Ranking position	Name	R&D expenditure (euros)	Total personnel (FTE)[a]	Researchers (FTE)[a]	Doctorate holders (FTE)[a]
1	Grupo Portugal Telecom	144,874,126	403.6	367.9	4.6
2	Bial—Portela & Cª, S.A.	55,648,267	80.6	76.3	20.1
3	Empresas Sonae	50,881,293	718.3	334.2	3.4
5	Grupo Unicer Bebidas de Portugal, SGPS, S.A.	40,529,224	22.7	22.7	3.0
7	Grupo José de Mello, SGPS, S.A.	24,493,985	254.3	198.3	9.1
13	CEIIA—Centro para a Excelência e Inovação na Indústria Automóvel	12,392,623	148.0	130.0	1.0
14	Hovione FarmaCiência, S.A.	11,497,709	141.0	82.0	16.0
17	Grupo Porto Editora	10.099,185	158.0	140.0	2.0
21	Tecnimede—Sociedade Técnico-Medicinal, S.A.	7,729,776	83.6	49.6	2.0
24	Grupo Galp Energia, SGPS, S.A.	7,266,291	40.7	39.9	2.3
27	Grupo ISQ	5,907,462	87.0	81.3	12.0
34	Fisipe—Fibras Sintéticas de Portugal, S.A.	4,982,699	40.0	29.0	2.0
38	Grupo SIBS	3,907,071	53.0	44.6	0.2
39	Grupo Empordef—Empresa Portuguesa de Defesa, SGPS, S.A.	3,850,363	98.4	81.4	0.5
40	Eurotrials—Consultores Científicos, S.A.	3,632,093	72.6	67.6	2.0
41	Logicati Portugal, S.A.	3,599,191	63.0	63.0	0.4
42	Grupo RAR	3,514,447	42.4	35.7	1.5
46	Grupo AdP—Águas de Portugal, SGPS, S.A.	3,282,880	64.1	51.7	1.2
47	Boehringer Ingelheim, Lda.	3,258,231	115.1	115.1	2.6

(continued)

Table 9.2 (continued)

Business enterprises with increased R&D expenditure in 2012					
Ranking position	Name	R&D expenditure (euros)	Total personnel (FTE)[a]	Researchers (FTE)[a]	Doctorate holders (FTE)[a]
52	Biocant—Associação de Transferência de Tecnologia	2,904,922	43.8	42.8	10.8
56	Frulact—Indústria Agro-Alimentar, S.A.	2,749,182	39.0	23.0	4.0
64	Deimos Engenharia, S.A.	2,419,493	33.7	33.7	5.0
65	Grupo Caixa Geral de Depósitos	2,331,045	37.0	31.9	0.4
66	ISA—Intelligent Sensing Anyware, S.A.	2,303,842	61.3	60.9	5.3
71	Construlink—Tecnologias de Informação, S.A.	2,156,744	50.0	35.0	0.7
74	Grupo Durit	na	20.3	12.5	1.8
81	Grupo Banif, SGPS, S.A.	1,902,504	16.1	16.1	0.1
89	Grupo CIN	1,692,693	37.9	20.9	0.8
95	Grupo Altri, SGPS, S.A.	1,570,498	15.3	12.2	1.2

Available in http://www.dgeec.mec.pt/np4/206/%7B$clientServletPath%7D/?newsId=11&fileName=Ranking2012_PublicacaoEmpresas_022015.pdf
Source: DGEEC/MEC, R&D Survey 2012 (IPCTN12)
[a]Full-time equivalent

business enterprise sector. In addition, we find that the number of doctorates with double appointments, in addition to their academic position, with participation in business sector, has been growing. In 2009, 2.6 % of doctorate holders were working in the business sector as their principal job, in many cases combining it with an academic position. If we count the doctorate holders that work at firms as their main and secondary jobs, the percentage of doctorate holders working in firms rises to 8.7 % in 2009.

In addition to the double appointments, we have seen an increase in the number of doctorates that found their own firms, making entrepreneurial activity a viable alternative in the labor market. According to the CDH-2006, 371 doctorate holders declared that they had established a new firm in the period between 2004 and 2006. Even though this number is still insignificant, there is some evidence that it is a growing phenomenon (Mendonça et al. 2015).

Finally, Fig. 9.7 presents the main careers for Portuguese doctorate holders in 2009. The main professional path for doctorate holders in Portugal is academia,

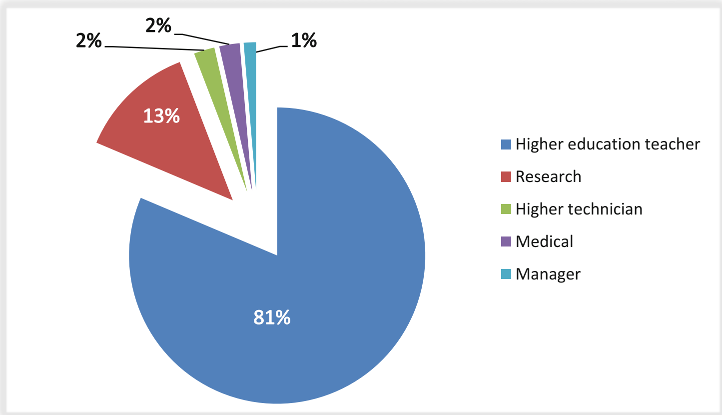

Fig. 9.7 Doctorate holders by main professional careers, 2009. *Source*: DGEEC/MEC, CDH-2009

with 81 % of employed doctorate holders working at university and polytechnics institutions, either public or private, followed by 13 % of doctorate holders working in a research career. Medical and health careers (including nursing and heath technicians) and higher technicians represent each 2 % of doctorate holders in these careers and managers account only for 1 % of doctorate holders.

9.3 Data and Methods

The data used in this paper is drawn from the CDH data based, which has been collected through a survey by the Portuguese Ministry of Education and Science since 2004. The data collection applies to all individuals under 70 years old, who lived (temporarily or permanently) in Portugal and held a doctoral degree (ISCED level 6), obtained anywhere in the world. This survey collects biographic data on the doctorates, their occupation—including sector of performance, careers, wages and mobility across sectors—and international mobility. This survey is conducted in several OECD countries under the same concepts, methodological guidelines and a harmonized core model questionnaire in a dedicated survey. We present the results from the CDH-2009 data collection for 2009, and the results of the KnowInno project, developed by the OECD with the participation of ten countries: Belgium, Denmark, France, Portugal, Spain, Russia, the United Kingdom, the United States, Israel, and Japan.

Our analysis is focused in four EU countries—Belgium, Denmark, Spain and Portugal. Portugal and Belgium have with similar size and population; Denmark has half the population of Belgium and Portugal, but was chosen as a Northern country with characteristics that are comparable with Belgium; Spain shares similarities with Portugal in the organization of the scientific system and geographical proximity. The main indicators that result from CDH collection of data suggest two types of patterns with respect to the ability to train and integrate these doctorate holders, which is related with the countries' scientific and higher education systems.[3] Following this suggestion, we consider Belgium and Denmark 'Northern countries' and Portugal and Spain 'Southern countries' in this work.

9.4 CDH-2009

In this section we present the main results of the CDH for the countries presented, which contain the main variables used for analysis. In Fig. 9.8 we observe the number of doctorate holders per country in 2009, showing Belgium with 3.1 doctorate holders per thousand population and 7.0 per active labor force, Denmark with 2.7 and 5.1, respectively. In the southern countries, Spain had 1.8 per thousand population and 3.6 doctorates by active labor force and Portugal had 1.7 per thousand population and 3.3 per active labor force.

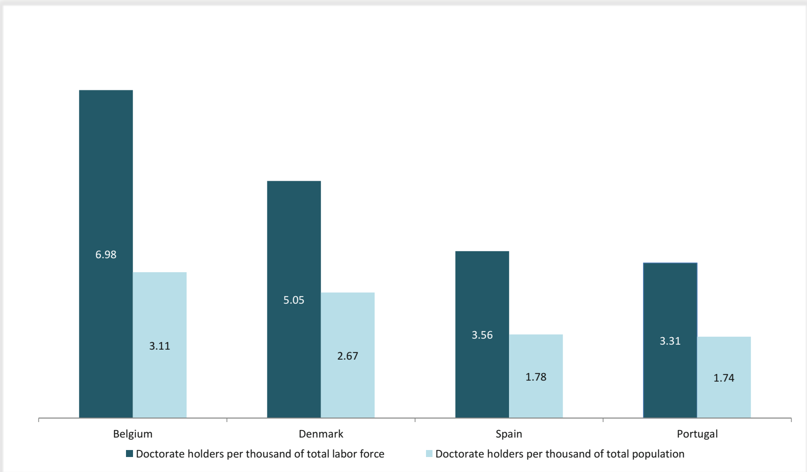

Fig. 9.8 Doctorate holders per thousand population and per thousand labour force by country, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010; OECD Main science and technology indicators, OECD Education attainment database, US Census Bureau (ACS 2009)

[3] For further international comparisons please check CDH-2009 results in: http://www.oecd.org/innovation/inno/oecdunescoinstituteforstatisticseurostatcareersofdoctorateholderscdhproject.htm

Figure 9.9 presents the growth rates in the numbers of doctorate holders per country, showing that southern countries are growing at higher rates than half of the countries and more than the average of the European Union.

Figure 9.10 presents the distribution of doctorates by gender, and the southern countries—Portugal and Spain—have more women with a doctoral degree (44 %) while in the northern countries—Belgium and Denmark—the average number of women with a doctoral degree is 35 %. Although the presence of women is higher than men among more highly educated human resources, the structure of the doctoral population is still dominated by men in all countries.

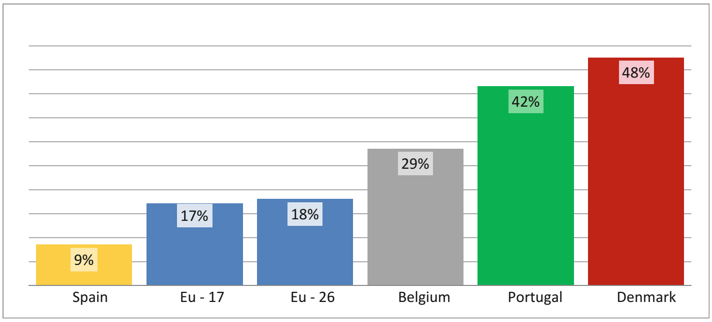

Fig. 9.9 Growth rate of doctorates holders by country, 2004–2009. *Source*: Eurostat database on Education Statistics

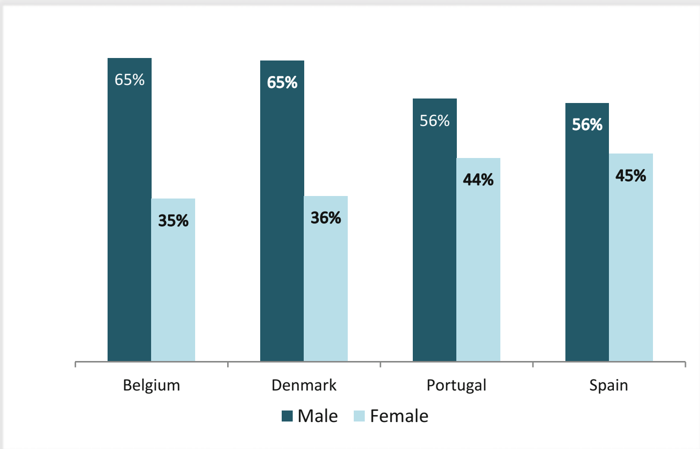

Fig. 9.10 Doctorate holders by country and gender, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

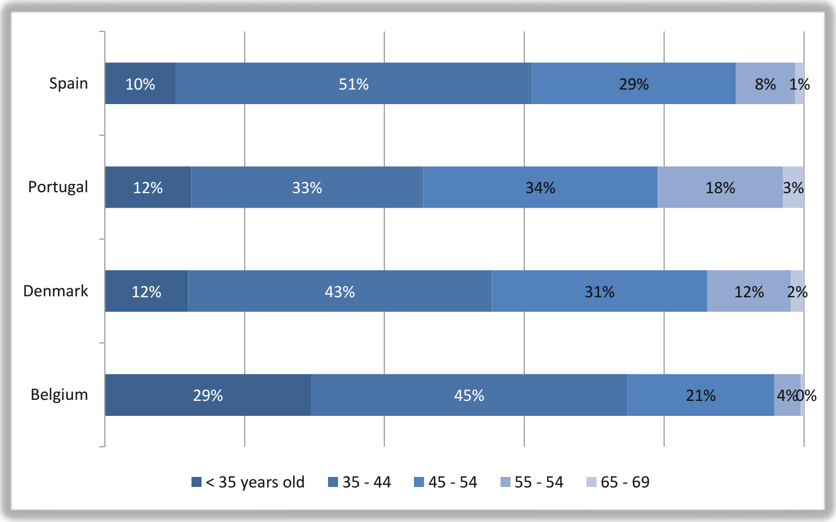

Fig. 9.11 Doctorate holders by age class and country, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

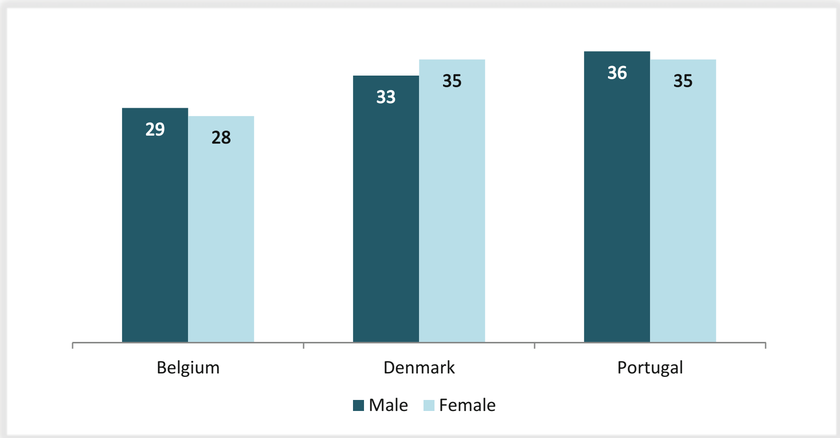

Fig. 9.12 Median age at graduation of recent graduates by country, 2009. *Note*: Data not available for Spain. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Regarding the age patterns presented in Fig. 9.11, we observe that there are no relevant differences between the two groups of countries. Belgium has a younger doctorate population with 29 % of their doctorates who are less than 35 years old, followed by Portugal with 15 %, Spain with 12 % and finally Denmark with 11 %.

This is also evident in the Fig. 9.12, which shows the median age at graduation of recent doctorates. Belgians obtained their doctoral degree 5–6 years (at 29 years

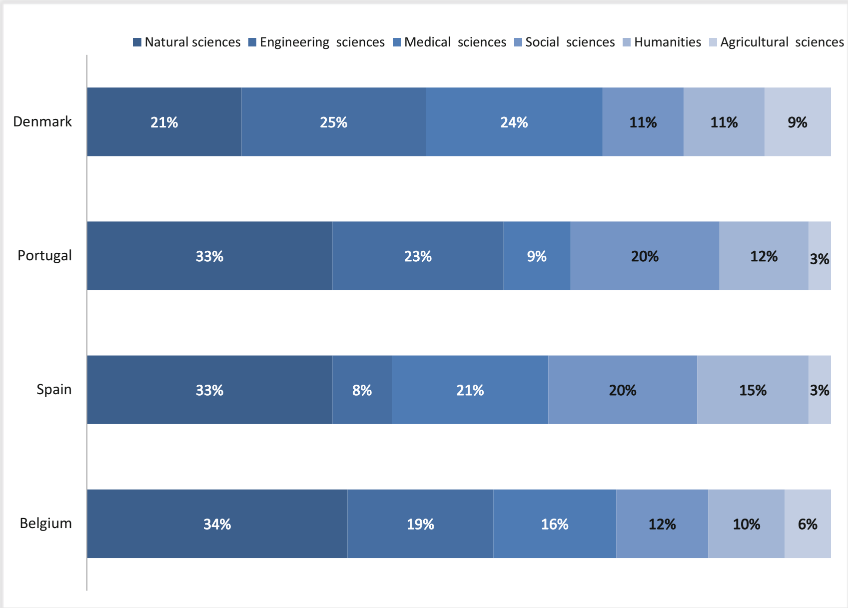

Fig. 9.13 Doctorate holders by field of science and country, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

old) earlier than their Portuguese (35 years old) and the Danish (34 years old) counterparts.

Figure 9.13 presents the distribution of doctorates by field of science.[4] Belgium, Portugal and Spain have the highest share of doctorate holders in natural sciences with 34 % of Belgian doctorates and 33 % of Portuguese and Spanish doctorates. Denmark has the highest share of doctorate holders in engineering and technology with 25 %, showing different patterns of specialization.

In Fig. 9.14 we present the unemployment rate for doctorate holders for these countries, which has remained low.

The unemployment rate, although low in all the four countries, is higher for young doctorates, resulting in many cases from a lack of opportunities for doctorates on the labor market (Mangematin 2000). However, reports from CDH survey respondents also suggest that some individuals choose to be out of the labor market, and are therefore considered unemployed.

[4] Careers on Doctorate Holders survey use the Fields of Science and Technology (FOS) international classification. The six main scientific areas are: natural sciences, engineering and technology, medical sciences, agricultural sciences, social sciences and humanities. For more information see http://www.oecd.org/innovation/inno/frascatimanualproposedstandardpracticeforsurveysonresearchandexperimentaldevelopment6thedition.htm#fos

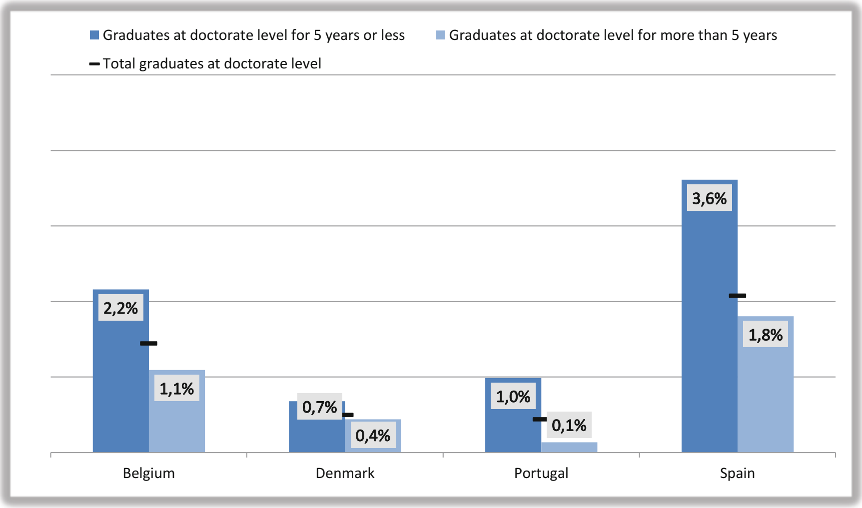

Fig. 9.14 Unemployment rates of former and recent doctorate holders by country, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

In addition, we observe that permanent positions are decreasing, especially for recent doctorates, followed by a growth of temporary contracts, adding to the belief that precarious job positions have been offered to doctorate holders since the 1990s, widening the gap between those who have a permanent position and those who are underemployed (Mangematin 2000). Figure 9.15 shows the type of contracts doctorates holders have in three of the four countries under analysis.

As can be seen in the figure, there is a high number of individuals with temporary contracts in all countries. One form of a precarious position is a post-doctoral period that has become increasingly common after concluding doctoral studies, resulting from an increasing imbalance between the number of tenured track positions in higher education and the number of doctorates (Horta 2009). In Portugal, where 33 % of doctorate holders have a temporary contract, the evolution of the post-doctoral recipients in the last 40 years has grown substantially. In Fig. 9.16 we show the percentage of doctorate holders with a post-doctoral position[5] over the last four decades. This figure shows a significant increase of this percentage, from 3 % in 1970s to 68 % in 2000s.

[5] Accordingly with the CDH instruction manual, "a postdoc position is generally understood as a temporary position for holders of advanced research qualifications (i.e. after finalising their advanced research qualification studies) where the main activity is research, and the holder receives some kind of financial support. However, there are very different forms of postdoc positions worldwide" (Auriol et al. 2012).

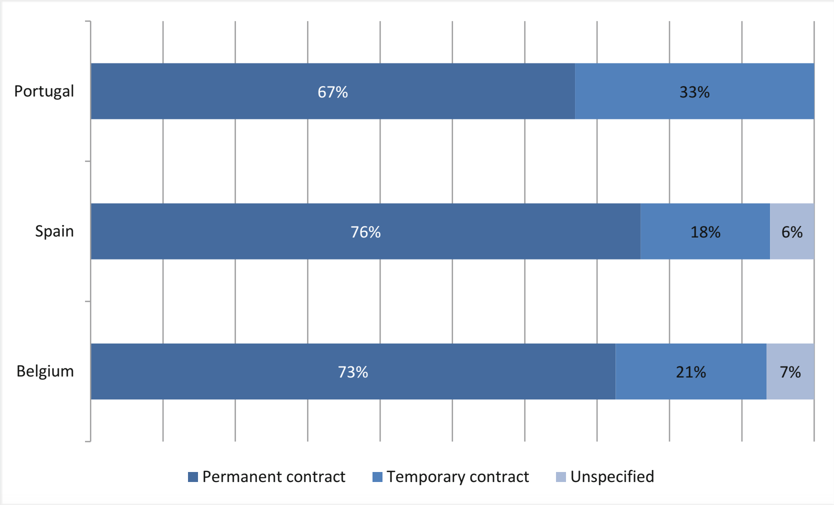

Fig. 9.15 Employed doctorate holders by country and type of contract, 2009. *Note*: n. e. = not specified. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

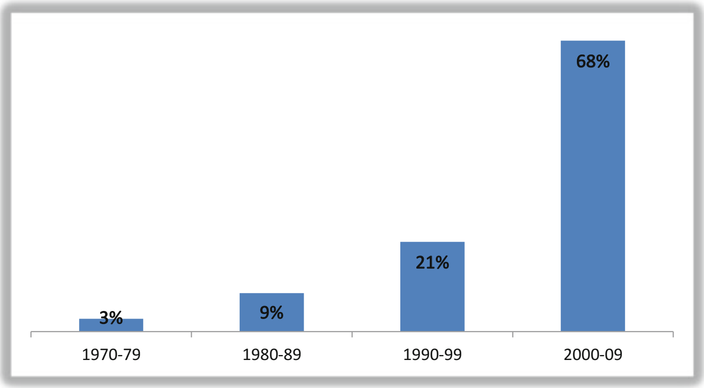

Fig. 9.16 Portuguese doctorate holders with a post-doctoral position by decade (%). *Source*: DGEEC/MEC, CDH-2009

9.5 Methods

In this paper, we make use of regression analysis to study a series of different determinants of career paths of doctorate holder in each country. Regression method is a statistical process that estimates the relationships between variables and focuses on the relationship between a dependent variable and one or more independent variables, allowing one to go further in the explanation of the conditions in which some things occur. For instance, while the CDH-2009 main results gives us the state of doctoral careers and mobility in each country, the regression analysis gives us the circumstances in which these things happen, what behaviour can we expect if the context remains and what can be expected if these circumstances change. The regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is changed, while the other independent variables are held fixed. It estimates the conditional expectations of the dependent variable given the independent variables—that is, the average value of the dependent variable when the independent variables are fixed. And it is also of interest to characterize the variation of the dependent variable around the regression function, which can be described by a probability distribution. Finally, regression analysis is widely used for prediction and forecasting. It is also used to understand, which variable among the independent variables are related to the dependent variable, and to explore the forms of these relationships.

We use logistic or logit regressions to study the determinants of a set of different career options for doctorates: being a researcher, experiencing mobility in their career, whether it is inter-sector or international. The logit regression is used to predict a binary response from a binary predictor, used for predicting the outcome of a categorical dependent variable based on one or more predictor variables. That is, it is used in estimating the parameters of a qualitative response model, such as the probabilities describing the possible outcomes, as a function of the explanatory (predictor) variables, using a logistic function (Wooldridge 2002). In this case, we estimate logistic regressions to predict the probability of a doctorate being engaged in research activities using explanatory variables such as the time since graduation, age, sex, field of science and sector of employment. On a second analysis we use the same set of predictors to determine their effect on mobility in careers, including intra-sector mobility, inter-sector mobility and international mobility.

In addition, we estimate an earnings equation to identify the main factors determining differences in earnings for doctorate holders. In this case we use a linear regression analysis, using as a dependent variable the annual earnings of doctorates (in logarithm), and as explanatory variables: the time since graduation, working hours, sex, field of study, sector of employment, engagement in research activities (binary variable), permanent position (binary variable), and international mobility in the last 10 years (binary variable).

9.6 Results

In this section we explore the results of the CDH for the four countries in analysis, making use of micro-data[6] for Belgium, Denmark, Portugal and Spain. We perform a regression analysis to identify the determinants of being a researcher, of gross annual earnings, and of having job mobility, including inter-sector and international mobility.

Following the CDH guidelines (Auriol et al. 2012), we define a recent doctorate as someone who has obtained the degree between 2008 and 2009, using the term "former" doctorates for those who obtained their doctoral degree before 2008.

9.6.1 Career Paths and Earnings

We begin by looking at the determinants of doctorate holders to devote to a research career. In Fig. 9.17 we present the distribution of doctorate holders by research status for each country, showing that for Spain and Belgium non-researchers are roughly one third of all doctorates, and in Portugal there is a much smaller number of non-researchers.

In Table 9.3 we present the results of a logit regression to analyse the factors determining being a researcher for doctorate holder in the four countries: Belgium, Denmark, Portugal and Spain.

According to these results, experience is one of the requirements for doctorate holders to become researchers in Portugal and Denmark. For each year after graduation, Portuguese doctorates have 14 % more chance of becoming researchers, and Danish doctorates are 6 % more likely to become researchers. For Belgium and Spain, recent doctorates that are more likely to become researchers are fewer, respectively, 6 % and 8 % more of a change of becoming researchers for every year after graduation. The results on gender tell us that opportunities are not equal for men and women, as women are less likely than men to become researchers in all the countries of our analysis: 50 % less in Belgium, 28 % less in Denmark, 18 % less in Spain and 12 % less in Portugal. Age is not a significant variable for Belgium and Denmark to explain the determinants of being a researcher, but in the southern countries is: in Portugal and Spain, for each year that doctorates grow older, the fewer chances they have of becoming researchers: 5 % fewer chances in Portugal and 4 % fewer chances in

[6] The OECD developed a project to explore and compare micro-data within countries, which required the creation of a universal coding guide and data harmonization of the participant ten countries.

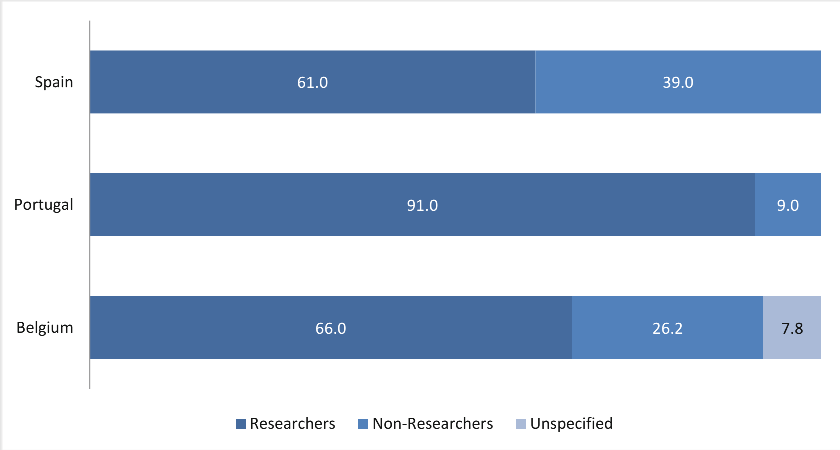

Fig. 9.17 Employed doctorate holders by country and research status, 2009. *Note*: Breakdown by researchers and non-researchers not available for Denmark; *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Spain (see Table 9.3). By field of science, and when compared with the doctorate holders from natural sciences, all scientific fields show fewer chances in Denmark and Portugal, with the exception of the agricultural sciences in Denmark for which results are not significant. In the medical sciences, only doctorate holders from Spain are 61 % less likely to become researchers than those in natural sciences. Agricultural sciences is a field of science that has no significance when compared with those from natural sciences in the Northern countries, and in the southern countries doctorates have 65 % fewer chances in Portugal than those in the natural sciences to become researchers. Doctorate holders from social sciences and humanities in Spain have 30 % and 41 % fewer chances, respectively, of becoming researchers than those in natural sciences. By sector of employment, and against the business sector, doctorate holders that work in the government sector have fewer chances of becoming researchers in the Northern countries, with 17 % fewer chances in Denmark and 30 % fewer chances in Belgium. In fact, a study among Danish academic staff argues that almost no doctorate would prefer to be in a purely research institution (Jesen 1988), which can explain the decreased likelihood of these individuals becoming a researcher in the government sector. For the southern countries, the chances of becoming a researcher increase when doctorate holder works in the government sector, there are 155 % more chances in Portugal due to the weight of the state laboratories and 185 % more chances in Spain, a natural consequence of the specific organization of the research system and the weight of the government sector. In the higher education sector, doctorate holders for all four countries have the best chances of becoming researchers, mostly when compared

Table 9.3 Determinants of being a researcher (logit regression weighted) by country, 2009

		Nordic countries								Southern countries							
		Belgium (2009)				Denmark (2009)				Portugal (2009)				Spain (2009)			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Independent variables		engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres
Time since graduation		**−0.024*****	**−0.089*****	**−0.090*****	**−0.062****	**−0.011****	0.022	0.022	**0.054****	**0.038*****	**0.092*****	**0.150*****	**0.134*****	0.009	−0.044	−0.014	**−0.078****
		(0.007)	(0.029)	(0.029)	(0.030)	(0.005)	(0.020)	(0.020)	(0.021)	(0.004)	(0.010)	(0.011)	(0.011)	(0.007)	(0.035)	(0.035)	(0.040)
Age				**0.001***	0.001			**−0.001*****	**−0.001*****			**−0.050*****	**−0.047*****			**−0.049*****	**−0.041*****
				(0.000)	(0.000)			(0.000)	(0.000)			(0.004)	(0.004)			(0.005)	(0.006)
Sex (against Male)	Female	**−0.669*****	**−0.670*****	**−0.673*****	**−0.702*****	**−0.319*****	**−0.320*****	**−0.316*****	**−0.325*****	−0.076	−0.070	**−0.107****	**−0.129****	−0.086	−0.086	**−0.189*****	**−0.199*****
		(0.075)	(0.075)	(0.075)	(0.079)	(0.051)	(0.051)	(0.051)	(0.053)	(0.053)	(0.053)	(0.054)	(0.055)	(0.067)	(0.067)	(0.068)	(0.077)
Field of study (against natural sciences)	Engineering	**0.204****	**0.195***	**0.190***	0.129	**−0.243*****	**−0.241*****	**−0.244*****	**−0.239*****	**−0.294*****	**−0.288*****	**−0.203****	**−0.190****	0.147	0.149	**0.249***	0.036
		(0.103)	(0.103)	(0.104)	(0.108)	(0.083)	(0.083)	(0.083)	(0.087)	(0.086)	(0.086)	(0.086)	(0.087)	(0.133)	(0.133)	(0.135)	(0.159)
	Medical sciences	**0.219****	**0.212***	**0.208***	0.100	**−0.887*****	**−0.892*****	**−0.883*****	**−0.723*****	**−0.984*****	**−0.973*****	**−0.690*****	**−0.705*****	**−1.457*****	**−1.460*****	**−1.287*****	**−0.934*****
		(0.109)	(0.109)	(0.109)	(0.119)	(0.062)	(0.062)	(0.062)	(0.068)	(0.092)	(0.092)	(0.096)	(0.097)	(0.093)	(0.093)	(0.095)	(0.106)
	Agricultural sciences	−0.065	−0.069	−0.068	−0.099	0.146	0.150	0.148	−0.013	**−1.219*****	**−1.268*****	**−1.017*****	**−1.044*****	**−0.358***	**−0.359***	−0.282	−0.233
		(0.130)	(0.130)	(0.130)	(0.135)	(0.136)	(0.137)	(0.137)	(0.141)	(0.130)	(0.130)	(0.132)	(0.134)	(0.186)	(0.186)	(0.188)	(0.212)
	Social sciences	**0.214***	0.207	0.206	−0.092	**−0.228*****	**−0.225*****	**−0.224*****	**−0.591*****	**−1.109*****	**−1.114*****	**−0.776*****	**−0.776*****	−0.116	−0.114	0.097	**−0.361*****
		(0.127)	(0.127)	(0.127)	(0.135)	(0.081)	(0.081)	(0.081)	(0.088)	(0.074)	(0.075)	(0.080)	(0.081)	(0.094)	(0.094)	(0.098)	(0.114)
	Humanities	0.028	0.020	0.017	−0.209	**−0.801*****	**−0.807*****	**−0.803*****	**−1.269*****	**−0.618*****	**−0.626*****	**−0.222****	**−0.252****	**−0.482*****	**−0.483*****	**−0.230****	**−0.522*****
		(0.134)	(0.134)	(0.134)	(0.146)	(0.088)	(0.088)	(0.088)	(0.104)	(0.094)	(0.094)	(0.101)	(0.102)	(0.101)	(0.101)	(0.105)	(0.122)
Sector of employment (against business sector)	Government				**−0.359*****				**−0.189*****				**0.937*****				**1.046*****
					(0.118)				(0.063)				(0.147)				(0.113)
	Higher education				**0.953*****				**1.576*****				**1.157*****				**2.841*****
					(0.096)				(0.086)				(0.120)				(0.124)
	Other education				**−2.064*****				**−1.536*****				0.141				
					(0.305)				(0.120)				(0.174)				
	Private non-profit				0.031				−0.292				**0.384****				**1.605*****
					(0.131)				(0.213)				(0.173)				(0.200)
	Unknown				**0.552****				−0.367								**−0.916*****
					(0.274)				(0.229)								(0.273)

(continued)

Table 9.3 (continued)

	Nordic countries								Southern countries							
	Belgium (2009)				Denmark (2009)				Portugal (2009)				Spain (2009)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Independent variables	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres	engres
Constant	1.286***	1.496***	1.481***	1.200***	1.911***	1.809***	1.845***	1.596***	2.640***	2.478***	4.217***	3.125***	0.704***	0.919***	2.657***	1.292***
	(0.095)	(0.133)	(0.134)	(0.146)	(0.068)	(0.090)	(0.091)	(0.099)	(0.074)	(0.078)	(0.159)	(0.195)	(0.097)	(0.170)	(0.254)	(0.295)
Observations	3,928	3,928	3,928	3,928	10,748	10,748	10,748	10,748	18,662	18,662	18,662	18,662	4,123	4,123	4,123	4,123

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Notes:

engres = He/she is engaged in research and/or experimental development work

tpass = year of reference-year end octorate

Source: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

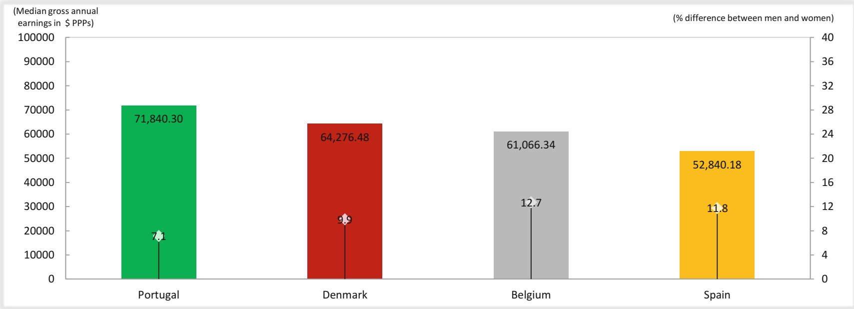

Fig. 9.18 Median gross annual earnings of doctorate holders in $ PPPs, 2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

with those working on firms; in Spain they have 1613 % more chances, in Denmark 384 % more chances, in Portugal 218 % more chances and in Belgium 159 % more chances of becoming researchers. In the private non-profit sector, data are only significant for southern countries with 398 % more chances in Spain and 47 % more chances in Portugal.

Turning to the issue of earnings, Fig. 9.18 presents the median gross annual earnings of doctorate holders in the four countries, showing values in percentages and in dollars in Purchase Power Parity (PPP).

Portugal shows higher earnings than the rest of the four countries, and a smaller difference between the gross annual earnings for men and women: 7 %. Subsequently we identify the determinants of earnings, obtained through an estimate with an earnings equation, shown in Table 9.4.

This regression looks at variables with an effect on gross annual earnings in three countries: Belgium, Portugal and Spain.[7] The results show that time since graduation affects the earning profiles of doctorate holders. For every year after the graduation, doctorate holders in Portugal and Spain have a 1 % higher chance of increasing their gross annual earnings, and doctorates in Belgium have 3 % higher chance of seeing an increase in their earnings. Gender has a direct impact on earnings, which has been extensively studied in the literature (see, for instance, Kunze 2005; Machin and Puhani 2003). Women are 6 % less likely to have higher earnings in Portugal, 10 % less likely in Belgium and 13 % less likely in Spain. Age appears to be an important factor in Portugal and Spain, as for each year a doctorate ages, the chances of having higher incomes increase by 1 %. Field of study will impact the earnings of doctorate holders. Doctorates in engineering and technology have a 7 % higher chance in Portugal of having better gross annual earnings than those in the natural sciences, a value which reaches 9 % in Belgium and 11 % in Spain. As for doctorates in the medical and health sciences, they are 25 % more likely to have better gross annual earnings than those in the natural sciences in

[7] Data on earnings is not available for Denmark.

Table 9.4 Determinants of gross annual earnings, 2009

		Nordic countries								Southern countries							
		Belgium (2009)				Denmark (2009)				Portugal (2009)				Spain (2009)			
		log (earning) lgearn				log (earning) lgearn				log (earning) lgearn				log (earning) lgearn			
Independent variables		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Time since graduation		**0.032*****	**0.032*****	**0.032*****	**0.030*****	na	na	na	na	**0.008*****	**0.007*****	**0.006*****	**0.005*****	**0.019*****	**0.019*****	**0.019*****	**0.014*****
		(0.001)	(0.001)	(0.001)	(0.001)					(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Age		0.000	0.000	0.000	0.000	na	na	na	na	**0.010*****	**0.010*****	**0.011*****	**0.009*****	**0.011*****	**0.011*****	**0.012*****	**0.009*****
		(0.000)	(0.000)	(0.000)	(0.000)					(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Working hours of present job (against full-time)	Part-time	**−0.181*****	**−0.172*****	**−0.169*****	**−0.159*****	na	na	na	na	**−0.046*****	**−0.026***	**−0.012**	**0.034****	**−0.429*****	**−0.423*****	**−0.416*****	**−0.327*****
		(0.025)	(0.025)	(0.025)	(0.025)					(0.014)	(0.014)	(0.014)	(0.014)	(0.030)	(0.030)	(0.030)	(0.030)
Sex (against Male)	Female	**−0.125*****	**−0.113*****	**−0.105*****	**−0.100*****	na	na	na	na	**−0.063*****	**−0.064*****	**−0.062*****	**−0.062*****	**−0.144*****	**−0.144*****	**−0.143*****	**−0.136*****
		(0.015)	(0.015)	(0.015)	(0.015)					(0.006)	(0.006)	(0.006)	(0.005)	(0.014)	(0.014)	(0.014)	(0.014)
Field of study (against natural sciences)	Engineering	**0.109*****	**0.091*****	**0.090*****	**0.090*****	na	na	na	na	**0.076*****	**0.075*****	**0.076*****	**0.063*****	**0.140*****	**0.139*****	**0.139*****	**0.105*****
		(0.018)	(0.018)	(0.018)	(0.018)					(0.007)	(0.007)	(0.007)	(0.007)	(0.027)	(0.027)	(0.027)	(0.027)
	Medical sciences	**0.257*****	**0.220*****	**0.219*****	**0.221*****	na	na	na	na	−0.017	−0.011	−0.005	−0.014	**0.237*****	**0.241*****	**0.249*****	**0.254*****
		(0.021)	(0.021)	(0.021)	(0.021)					(0.010)	(0.010)	(0.010)	(0.010)	(0.020)	(0.021)	(0.021)	(0.020)
	Agricultural sciences	**0.095*****	**0.089*****	**0.089*****	**0.087*****	na	na	na	na	0.027*	0.026	0.036**	0.032**	−0.011	−0.012	−0.011	−0.017
		(0.025)	(0.024)	(0.024)	(0.024)					(0.016)	(0.016)	(0.016)	(0.016)	(0.041)	(0.041)	(0.041)	(0.040)
	Social sciences	**0.108*****	**0.122*****	**0.124*****	**0.118*****	na	na	na	na	**0.077*****	**0.076*****	**0.083*****	**0.076*****	**0.068*****	**0.063*****	**0.065*****	**0.047****
		(0.024)	(0.024)	(0.024)	(0.023)					(0.008)	(0.008)	(0.008)	(0.008)	(0.020)	(0.020)	(0.020)	(0.020)
	Humanities	−0.019	0.019	0.024	0.020	na	na	na	na	−0.004	−0.010	−0.010	−0.006	**−0.135*****	**−0.139*****	**−0.136*****	**−0.144*****
		(0.026)	(0.026)	(0.026)	(0.026)					(0.010)	(0.010)	(0.010)	(0.010)	(0.023)	(0.023)	(0.023)	(0.022)
Sector of employment (against business sector)	Government		**−0.093*****	**−0.086*****	**−0.075*****	na	na	na	na		**0.052*****	**0.039****	**0.054*****		0.030	0.021	0.018
			(0.022)	(0.022)	(0.022)						(0.020)	(0.020)	(0.019)		(0.022)	(0.022)	(0.023)
	Higher education		**−0.099*****	**−0.111*****	**−0.081*****	na	na	na	na		**0.143*****	**0.128*****	**0.148*****		**0.040***	0.017	0.003
			(0.016)	(0.016)	(0.017)						(0.017)	(0.017)	(0.017)		(0.022)	(0.024)	(0.025)
	Other education		**−0.379*****	**−0.347*****	**−0.320*****	na	na	na	na		**−0.059****	**−0.053****	**−0.045***				
			(0.051)	(0.051)	(0.051)						(0.027)	(0.027)	(0.027)				
	Private non-profit		**0.096*****	**0.094*****	**0.098*****	na	na	na	na		0.016	0.008	0.041*		−0.014	−0.029	−0.035
			(0.025)	(0.025)	(0.024)						(0.023)	(0.023)	(0.022)		(0.040)	(0.040)	(0.040)
	Unknown		0.070	0.065	0.085	na	na	na	na			**0.125*****	**0.133*****				
			(0.067)	(0.067)	(0.067)							(0.010)	(0.009)				

Engagement in research activity (against non-researcher)	Researcher			**0.074*****	**0.076*****	na	na	na	na				**−0.133*****			**0.041****	**0.053*****
				(0.016)	(0.016)								(0.006)			(0.017)	(0.016)
	Unknown research status			0.040	0.052*	na	na	na	na				0.002				
				(0.030)	(0.029)								(0.007)				
Permanency of present job (against permanent)	Temporary				**−0.097*****	na	na	na	na	**4.268*****	**4.133*****	**4.011*****	**4.149*****				**−0.257*****
					(0.019)					(0.017)	(0.024)	(0.026)	(0.027)				(0.020)
	Unknown status				−0.045	na	na	na	na								**−0.179*****
					(0.045)												(0.032)
International mobility (against non-mobile)	Mobile in past 10 years				**0.046*****	na	na	na	na				0.542***				−0.014
					(0.017)								(0.055)				(0.018)
Constant		10.623***	10.676***	10.622***	10.631***	na	na	na	na	−0.326	−0.152	−0.266	−0.938***	9.941***	9.916***	9.889***	10.092***
		(0.017)	(0.019)	(0.022)	(0.023)					(0.283)	(0.306)	(0.312)	(0.333)	(0.044)	(0.047)	(0.048)	(0.051)
Observations		2,957	2,957	2,957	2,957	na	na	na	na	18,662	18,662	18,662	18,662	3,960	3,960	3,960	3,960
R-squared		0.232	0.266	0.271	0.279					0.152	0.164	0.171	0.190	0.228	0.229	0.230	0.267

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Notes:

1. lgearn = log(gearn) and gearn = Gross annual earnings converted into Euro for the year <200X)
2. Mid points for the gross annual earnings were used to estimate the results
3. Data not available for Dennmark

Source: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Belgium and 29 % more likely in Spain. Doctorates in agricultural sciences have 3 % more prospects of better earnings in Portugal, and a likelihood of 9 % in Belgium. When compared to natural sciences, social sciences doctorates in Spain are 5 % more likely to have better gross annual earnings, a probability which increases to 8 % in Portugal and 13 % in Belgium. Doctorate holders in the humanities in Spain are 13 % less likely to have higher gross annual earnings than those in the natural sciences.

The type of contract also has an effect on wages. In Portugal, doctorates working with a permanent contract have a 62 % higher likelihood of reaching a higher income when compared with those with a temporary contract. In Belgium and Spain we obtained the reverse effect, and doctorates with a permanent contract are less likely to have higher earnings (9 % less for Belgium and 23 % less for Spain).

In addition, doctorate holders that work full time in Portugal are more likely to have better earnings, but the opposite effect is observed for Belgium and Spain, where full time workers are less likely to have better earnings. This can mean that a part-time job in different countries has a completely different status. Also in Belgium and Spain, the results show that there is a wage premium for doctorate holders that work in research activities against those who work in non-research activities. On the other hand, for Portugal, doctorates that work in research activities have are 12 % less likely to have better earnings that those who work in non-research activities.

As to the sector of activity, the results show that a doctorate working in the government sector in Portugal will likely have higher income that those working in firms. The analysis shows a reverse effect for Belgium, where doctorates in the government sector have 7 % lower chance of having a higher income than those who work in firms. In addition, doctorates in the higher education sector in Spain and Portugal are more likely to have higher earnings, whereas in Belgium they will have lower earnings than those working in the private sector.

Mobile doctorates also have an advantage in terms of earnings, benefiting those in the southern countries, which according to Becker (1964), is expected since "the general human capital should be rewarded with a greater wage expectation when external job mobility occurs"; those doctorate holders who were mobile between 2000 and 2009 had 72 % more of a chance in Portugal and 5 % in Spain to gather higher gross annual earnings.

9.6.2 Mobility Patterns of Doctorate Holders

We now look at the mobility of doctorate holders, considering different types of mobility. In Fig. 9.19, we present the job mobility of doctorate holders in the last decade for the countries studied. For Denmark there was a 76 % rate of job mobility between 2000 and 2009, which means that three out of four doctorate holders had job mobility. In Portugal, one out of four doctorate holders had job mobility, whereas in Spain and Belgium less than one out of four doctorate holders had job mobility.

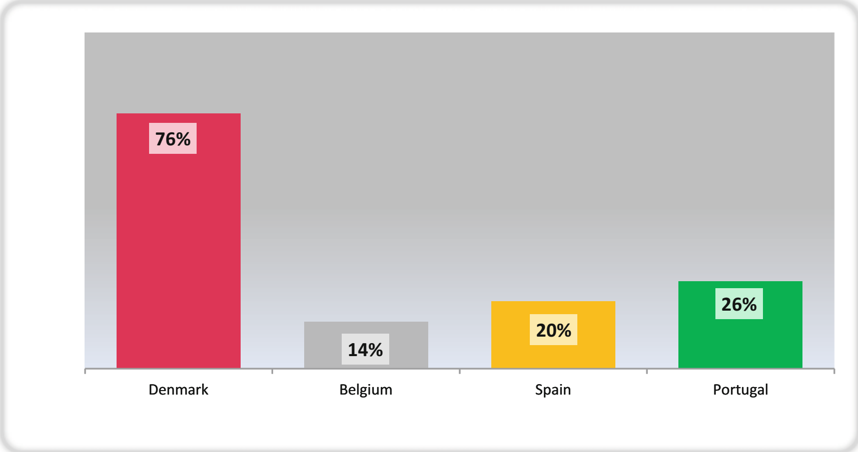

Fig. 9.19 Job mobility of employed doctorate holders by country, 2000–2009. *Source*: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Following this characterization, we present the results for a logit regression explaining the determinants of job mobility by country in Table 9.5.

The results show that the time since graduation has an effect on mobility. For Denmark every year after graduation affects job mobility positively by 20 % while in the southern countries these chances fall with every year that passes after graduation. A comparison of former doctorates with recent doctorates shows that the first always has more chances of having job mobility in the Northern countries and fewer chances in Portugal (37 %). And when we look only for the former doctorates in the table, the results confirm that those doctorates have more chances of having job mobility in the Northern countries, although chances are smaller than in the case in which we confront former against recent doctorates. For Portugal, former doctorates have more 3 % more chances of having job mobility. Thus, seniority is an important factor in promoting job mobility.

Additionally, the results show that gender is only significant for Portugal, where women have 17 % higher chances to experience job mobility than men. Doctorates in engineering have 15 % more chances of mobility in Denmark, and a lower probability of mobility in Portugal and Spain, when compared with natural sciences doctorates. For the medical and health sciences, doctorates have 42 % higher chances of mobility in Denmark, but are less likely to change jobs in Belgium and in Portugal, the result corresponds to the OECD's 2001 study that argues that health professionals have very little mobility and that doctors rarely changed jobs (OECD 2001). Doctorates in the agricultural sciences are less likely to be mobile in Portugal than those in the natural sciences. In the social sciences, doctorates in Portugal have a 30 % higher chance of mobility, whereas in Denmark and Belgium they are less likely to move. As for the humanities, doctorate holders have more

Table 9.5 Determinants of job mobility (logit regression) by country, 2009

		Nordic countries						Southern countries					
		Belgium (2009)			Denmark (2009)			Portugal (2009)			Spain (2009)		
		chjob			chjob			chjob			chjob		
Independent variables		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Time since graduation		−0.061	−0.057	−0.058	**0.184*****	**0.188*****	**0.204*****	**−0.031*****	−0.006	−0.005	**−0.115*****	**−0.115*****	**−0.102*****
		(0.039)	(0.040)	(0.040)	(0.010)	(0.011)	(0.011)	(0.007)	(0.009)	(0.009)	(0.025)	(0.026)	(0.026)
≥10 years since graduation (against ≤ 10 years since graduation)		**1.523*****	**1.667*****	**1.628*****	**1.283*****	**1.415*****	**1.488*****	**−0.373*****	**−0.481*****	**−0.462*****	0.175	0.114	0.120
		(0.483)	(0.492)	(0.494)	(0.216)	(0.219)	(0.219)	(0.095)	(0.112)	(0.112)	(0.425)	(0.432)	(0.434)
Time since graduation (only ≥10 years since graduation)		**−0.171*****	**−0.183*****	**−0.176*****	**−0.173*****	**−0.186*****	**−0.194*****	**0.028*****	**0.027*****	**0.027*****	−0.028	−0.022	−0.025
		(0.048)	(0.050)	(0.050)	(0.019)	(0.019)	(0.019)	(0.009)	(0.010)	(0.011)	(0.039)	(0.040)	(0.040)
Sex (against male)	Female	−0.090	−0.103	−0.071	0.003	−0.012	0.035	0.016	**0.156*****	**0.156*****	−0.100	−0.087	−0.103
		(0.127)	(0.129)	(0.130)	(0.046)	(0.046)	(0.047)	(0.035)	(0.042)	(0.042)	(0.083)	(0.086)	(0.086)
Field of study (against natural sciences)	Engineering	−0.004	−0.026	−0.012	0.035	0.097	0.138*	**0.153*****	**−0.120****	**−0.099***	**−0.381****	**−0.354****	−0.268
		(0.178)	(0.181)	(0.182)	(0.069)	(0.071)	(0.071)	(0.047)	(0.058)	(0.058)	(0.163)	(0.169)	(0.171)
	Medical sciences	**−0.505*****	**−0.492****	**−0.485****	**0.290*****	**0.271*****	**0.351*****	0.037	**−0.359*****	**−0.335*****	−0.084	−0.186	−0.052
		(0.184)	(0.191)	(0.192)	(0.058)	(0.062)	(0.063)	(0.064)	(0.076)	(0.076)	(0.115)	(0.122)	(0.125)
	Agricultural sciences	−0.109	−0.090	−0.075	0.099	0.031	0.049	0.019	**−0.298****	**−0.274****	−0.277	−0.226	−0.151
		(0.228)	(0.232)	(0.233)	(0.105)	(0.106)	(0.107)	(0.104)	(0.123)	(0.123)	(0.253)	(0.261)	(0.262)
	Social sciences	**−0.785*****	**−0.835*****	**−0.824*****	**−0.183*****	**−0.281*****	**−0.266*****	**0.418*****	**0.236*****	**0.262*****	−0.186	−0.015	0.112
		(0.190)	(0.197)	(0.198)	(0.066)	(0.067)	(0.067)	(0.047)	(0.057)	(0.057)	(0.115)	(0.120)	(0.123)
	Humanities	**−0.524****	**−0.491****	**−0.466****	−0.041	**−0.178****	−0.119	**0.254*****	0.100	**0.121***	−0.022	0.154	**0.269****
		(0.211)	(0.222)	(0.223)	(0.083)	(0.085)	(0.086)	(0.057)	(0.071)	(0.071)	(0.125)	(0.131)	(0.133)
Sector of origin (against business sector)	Government		−0.208	−0.248		**0.351*****	**0.365*****		**−1.451*****	**−1.452*****		**−1.031*****	**−1.079*****
			(0.222)	(0.223)		(0.062)	(0.062)		(0.081)	(0.081)		(0.111)	(0.112)
	Higher education		**0.389****	**0.335****		**0.606*****	**0.565*****		**−3.534*****	**−3.546*****		**−1.372*****	**−1.468*****
			(0.153)	(0.154)		(0.055)	(0.055)		(0.073)	(0.073)		(0.115)	(0.117)
	Other education		−0.261	−0.265		−0.129	−0.099		−0.361***	−0.352***			
			(0.413)	(0.414)		(0.114)	(0.115)		(0.100)	(0.100)			
	Private non-profit		−0.199	−0.190		**1.153*****	**1.180*****		**−1.573*****	**−1.579*****		−0.280	**−0.322***
			(0.220)	(0.220)		(0.258)	(0.259)		(0.099)	(0.099)		(0.188)	(0.189)
	Unknown		**−1.545*****	**−1.510*****		**0.759*****	**0.718*****					0.000	0.000
			(0.294)	(0.295)		(0.206)	(0.206)					(0.000)	(0.000)

International mobility (against non-mobile)	Mobile in past 10 years			**0.529*****			**0.329*****			**0.173*****			**0.586*****
				(0.165)			(0.091)			(0.053)			(0.101)
Constant		2.947***	2.865***	2.739***	−0.362***	−0.700***	−0.655***	−0.986***	1.456***	1.403***	−0.250	0.652***	0.387**
		(0.253)	(0.278)	(0.279)	(0.066)	(0.075)	(0.082)	(0.049)	(0.086)	(0.088)	(0.165)	(0.187)	(0.193)
Observations		2,358	2,358	2,358	10,748	10,748	10,748	18,662	18,662	18,662	4,123	3,960	3,960

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Notes:
chjob = He/she has changed jobs in the last 10 years
Source: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

chances of mobility in southern countries (31 % in Spain and 13 % in Portugal) and lower chances for job mobility in the Northern countries (16 % less in Denmark and 37 % less in Belgium). Regarding the sector, Danish doctorate holders working in the government are more likely to move when compared with doctorates in the business sector, with the opposite effect for Portugal and Spain. The higher education sector offers more chances of mobility in Northern countries than the business sectors, whereas in the southern countries the opposite is true.

International mobility has a direct effect on the opportunities for job mobility in all countries when compared with those doctorates that without an international mobility experience in the last 10 years. Figure 9.20 shows the type of professional mobility for those doctorate holders that had job mobility in the last decade, differentiating mobility across sectors or within the same sector but at different institutions.

We observe that Belgium had higher rates of intra-sector mobility (75 %) while Spain had the same share (50 %) for intra and inter-sector mobility. Portugal had an inverse pattern of mobility with 64 % of doctorate holders moving across sectors.

Table 9.6 presents the results identifying the inter-sector mobility among mobile doctorate holders. The regression on inter-sector mobility applies only to those doctorate holders that had professional mobility in the last 10 years (between 2000 and 2009). To highlight mobility patterns of doctorate holders, two types of job mobility were considered: one that is characterized by changes inside the same sector of employment (intra-sector mobility), while inter-sector mobility is characterized by changes across different sectors.

We once more observe the effect of the time since graduation, which has a direct impact on the chances of having inter-sector mobility increasing by 3 % in

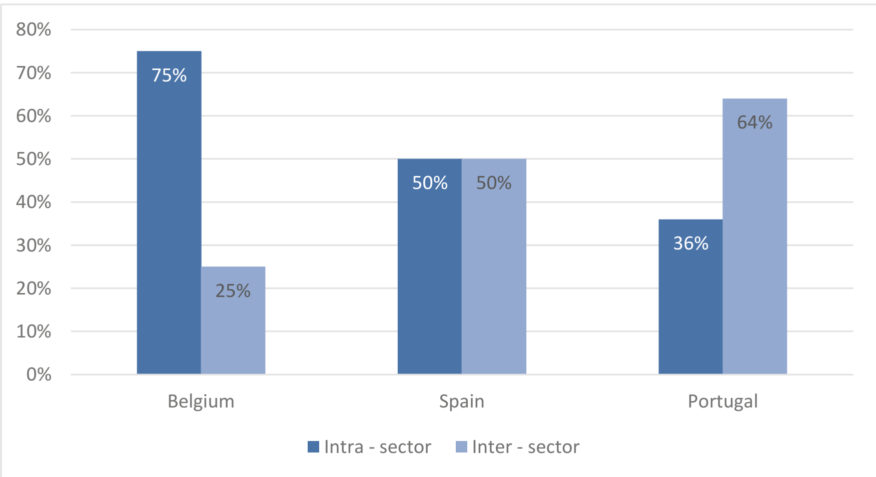

Fig. 9.20 Doctorate holders with job mobility by country and type of mobility, 2000–2009. *Note*: Data not available for Denmark; *Source*: OECD, based on OECD/UNESCO Institute for Statistics/ Eurostat data collection on careers of doctorate holders 2010

Table 9.6 Determinants of intersectoral mobility among mobile doctorate holders (logit regression) by country, 2009

		Nordic countries								Southern countries							
		Belgium (2009)				Denmark (2009)				Portugal (2009)				Spain (2009)			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Independent variables		intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec
Time since graduation		−0.005	0.013	0.016	0.020	**0.014****	**0.031****	**0.038*****	**0.036*****	0.003	**0.041*****	−0.029	−0.029	**−0.043****	**−0.086****	**−0.086***	**−0.090****
		(0.010)	(0.024)	(0.025)	(0.025)	(0.006)	(0.013)	(0.014)	(0.014)	(0.005)	(0.014)	(0.022)	(0.022)	(0.019)	(0.043)	(0.045)	(0.045)
10 years or longer since graduation (against < than 10 years since graduation)			−0.023	0.065	0.133		0.049	0.282	0.272		**0.688*****	**−0.947*****	**−0.965*****		−0.226	−0.295	−0.294
			(0.440)	(0.453)	(0.455)		(0.230)	(0.243)	(0.243)		(0.192)	(0.273)	(0.274)		(0.786)	(0.812)	(0.811)
Time since graduation (only ≥10 years or longer since graduation)			−0.013	−0.019	−0.030		−0.016	−0.035	−0.035		**−0.068*****	**0.090*****	**0.090*****		0.048	0.058	0.058
			(0.039)	(0.040)	(0.041)		(0.021)	(0.022)	(0.022)		(0.017)	(0.026)	(0.026)		(0.071)	(0.073)	(0.073)
Sex (against male)	Female	0.013	0.011	−0.029	−0.074	**0.125****	**0.126****	0.055	0.044	**−0.384*****	**−0.369*****	**−0.182***	**−0.180***	0.145	0.144	0.197	0.202
		(0.100)	(0.100)	(0.103)	(0.105)	(0.052)	(0.052)	(0.055)	(0.055)	(0.065)	(0.066)	(0.102)	(0.102)	(0.149)	(0.149)	(0.154)	(0.154)
Field of study (against natural sciences)	Engineering	−0.130	−0.124	−0.051	−0.076	**−0.193****	**−0.191****	0.094	0.091	**1.057*****	**1.097*****	**1.187*****	**1.178*****	**0.589****	**0.587***	0.463	0.439
		(0.131)	(0.131)	(0.135)	(0.136)	(0.077)	(0.077)	(0.082)	(0.083)	(0.093)	(0.094)	(0.138)	(0.139)	(0.300)	(0.301)	(0.311)	(0.312)
	Medical sciences	−0.080	−0.074	**−0.268***	**−0.273***	**−0.757*****	**−0.758*****	**−0.852*****	**−0.872*****	**0.792*****	**0.839*****	**1.027*****	**1.023*****	**0.463****	**0.467****	**0.623*****	**0.580*****
		(0.146)	(0.147)	(0.157)	(0.157)	(0.065)	(0.065)	(0.073)	(0.074)	(0.124)	(0.125)	(0.180)	(0.180)	(0.206)	(0.207)	(0.217)	(0.222)
	Agricultural sciences	0.019	0.024	0.035	0.042	**−0.255****	**−0.256****	**−0.240****	**−0.244****	**1.379*****	**1.386*****	**1.310*****	**1.301*****	**0.867***	**0.867***	**1.011****	**0.974***
		(0.169)	(0.169)	(0.175)	(0.175)	(0.117)	(0.117)	(0.122)	(0.122)	(0.240)	(0.240)	(0.341)	(0.342)	(0.482)	(0.482)	(0.497)	(0.499)
	Social sciences	−0.178	−0.175	**−0.314***	**−0.343****	**−0.495*****	**−0.492*****	**−0.637*****	**−0.648*****	**0.632*****	**0.663*****	**0.707*****	**0.692*****	**0.449****	**0.462****	**0.496****	**0.457****
		(0.163)	(0.163)	(0.168)	(0.169)	(0.081)	(0.081)	(0.085)	(0.085)	(0.084)	(0.084)	(0.130)	(0.132)	(0.205)	(0.206)	(0.214)	(0.219)
	Humanities	**−0.589*****	**−0.576*****	**−0.842*****	**−0.867*****	**−0.630*****	**−0.635*****	**−0.966*****	**−0.987*****	**0.851*****	**0.864*****	**0.667*****	**0.662*****	**0.532****	**0.540****	**0.587****	**0.556****
		(0.183)	(0.184)	(0.194)	(0.196)	(0.099)	(0.099)	(0.104)	(0.105)	(0.109)	(0.109)	(0.182)	(0.182)	(0.222)	(0.223)	(0.232)	(0.235)
Sector of origin (against business sector)	Government sector			**1.061*****	**1.130*****			**1.100*****	**1.106*****			−0.057	−0.056			**−1.028*****	**−1.010*****
				(0.194)	(0.196)			(0.080)	(0.080)			(0.149)	(0.149)			(0.191)	(0.192)
	Higher education			**0.425*****	**0.511*****			**1.304*****	**1.314*****			**−3.822*****	**−3.816*****			**−0.407****	**−0.382***
				(0.120)	(0.122)			(0.069)	(0.069)			(0.128)	(0.128)			(0.195)	(0.197)
	Other education			**2.459*****	**2.517*****			**3.103*****	**3.102*****			0.000	0.000				
				(0.448)	(0.450)			(0.210)	(0.210)			(0.000)	(0.000)				
	Private non-profit			**1.465*****	**1.505*****			**3.163*****	**3.181*****			−0.277	−0.283			**1.153*****	**1.163*****
				(0.198)	(0.199)			(0.302)	(0.303)			(0.196)	(0.196)			(0.390)	(0.391)

(continued)

Table 9.6 (continued)

		Nordic countries								Southern countries							
		Belgium (2009)				Denmark (2009)				Portugal (2009)				Spain (2009)			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Independent variables		intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec	intersec
International mobility (against non-mobile)	Mobile in past 10 years				**−0.484*** **				0.125				−0.085				−0.151
					(0.112)				(0.100)				(0.126)				(0.176)
Constant		−0.280**	−0.359**	−0.803***	−0.702***	−0.083	−0.164*	−1.180***	−1.260***	0.393***	0.208**	1.755***	1.781***	0.132	0.346	0.662**	0.746**
		(0.124)	(0.160)	(0.188)	(0.190)	(0.067)	(0.088)	(0.105)	(0.113)	(0.076)	(0.091)	(0.162)	(0.167)	(0.197)	(0.279)	(0.311)	(0.327)
Observations		1,907	1,907	1,907	1,907	7,149	7,149	7,149	7,149	4,846	4,846	4,010	4,010	778	778	778	778

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: intersec = He/she had intersectoral mobility

Source: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Denmark and 4 % in Portugal, and an 8 % likelihood of falling in Spain. When compared with recent doctorates, former doctorates have 62 % fewer chances of having inter-sector mobility in Portugal, maybe due to having obtained their degree at a time when academia was the main career option for doctorates. In Portugal, accordingly to CDH-2009 data, 69 % of the employed doctorate holders obtained their doctoral degree in a working context and 58 % did it probably as a career progression requirement in higher education. In 2009, with the approval of the new regulation for academic careers, the requirements to enter in the academic career became the doctoral degree.[8]

Within the group of doctorate holders with professional mobility, women in Denmark are 13 % more likely to have inter-sector mobility and in Portugal they are 31 % less likely to have this type of mobility. Determinants of inter-sector mobility by field of science shows that doctorate holders in engineering have more chances than those in natural sciences to have inter-sector mobility in the southern countries, and fewer chances in Denmark. A similar trend is observed for doctorates in medical and health sciences which have higher chances of inter-sector mobility than those in natural sciences in southern countries, with an opposite result for the Northern countries. The same effects are observed for doctorates in the agricultural sciences and for doctorates in the social sciences and in the humanities.

Inter-sector mobility by sector of employment is also an important aspect. We observe that compared with the business enterprise sector, doctorate holders that work in the government sector and in the higher education sector in the Northern countries have more chances of having inter-sector mobility, while in the southern countries the effect is the opposite. For the private non-profit sector, Northern counties again show higher chances of inter-sector mobility than that working in the business enterprise sector, and the same effect was obtained for Spain. International mobility experience in the last decade (between 2000 and 2009) means having 38 % fewer chances of having inter-sector mobility in Belgium when compared with those doctorates that did not have job mobility.

We continue by looking specifically at the determinants of international mobility per country, presented in Table 9.7, since transnational mobility is now considered an essential part of an academic career path and is integral to an academic's recognition and reputation (Recotillet 2007).

The results reveal that gender also has an impact on international mobility and in order to solve the difficulties experienced by young female doctorates in combining career and family roles, specific programs have been developed or still need to be developed in order to facilitate the international mobility of young researchers—to take into account the specificities of research careers—and to promote gender equality on these aspects and also a more general cultural change in the scientific community seems to be needed to facilitate progress towards gender equality (Moguérou 2005). Women have always had fewer chances of having an

[8] Law 205/2009 and law 207/2009 of the 31st of August 2009 (see http://dre.tretas.org/dre/259825/ and http://dre.tretas.org/dre/259826/).

Table 9.7 Determinants of international mobility (logit regression) by country, 2009

		Nordic countries				Southern countries			
		Belgium (2009)		Denmark (2009)		Portugal (2009)		Spain (2009)	
		intmob		intmob		intmob		intmob	
Independent variables		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Time since graduation		**−0.062*****	0.011	**−0.067*****	**−0.147*****	**−0.063*****	−0.014*	**−0.123*****	**−0.124*****
		(0.008)	(0.018)	(0.010)	(0.020)	(0.003)	(0.008)	(0.010)	(0.025)
≥10 years since graduation (against <10 years since graduation)			**0.785****		**1.249****		**−0.672*****		**0.458**
			(0.400)		(0.547)		(0.124)		(0.401)
Time since graduation (only 10 years or longer since graduation)			**−0.117*****		−0.020		**−0.011**		−0.031
			(0.034)		(0.047)		(0.010)		(0.038)
Sex (against male)	Female	**−0.455*****	**−0.456*****	**−0.193****	**−0.214****	**0.086****	**0.088****	**0.116**	**0.119**
		(0.085)	(0.085)	(0.091)	(0.091)	(0.039)	(0.039)	(0.081)	(0.081)
Field of study (against natural sciences)	Engineering	**−0.376*****	**−0.349*****	**−0.273****	**−0.323****	**−0.772*****	**−0.762*****	**−0.739*****	**−0.739*****
		(0.110)	(0.110)	(0.135)	(0.136)	(0.053)	(0.053)	(0.150)	(0.150)
	Medical sciences	**−0.269****	**−0.249****	**−0.397*****	**−0.437*****	**−0.925*****	**−0.893*****	**−1.433*****	**−1.434*****
		(0.117)	(0.118)	(0.134)	(0.135)	(0.075)	(0.075)	(0.130)	(0.130)
	Agricultural sciences	−0.194	−0.172	0.233	0.216	−0.750***	−0.775***	−0.466**	−0.467**
		(0.144)	(0.144)	(0.185)	(0.188)	(0.120)	(0.120)	(0.221)	(0.221)
	Social sciences	−0.111	−0.094	**0.485*****	**0.460*****	−0.885***	−0.890***	**−0.937*****	**−0.938*****
		(0.127)	(0.127)	(0.112)	(0.113)	(0.054)	(0.054)	(0.113)	(0.113)
	Humanities	−0.260*	−0.232	**0.621*****	**0.622*****	−0.810***	−0.812***	**−0.876*****	**−0.874*****
		(0.143)	(0.143)	(0.159)	(0.160)	(0.067)	(0.067)	(0.126)	(0.126)
Constant		−0.692***	−1.010***	−0.557***	−0.255**	−0.453***	−0.585***	0.297***	0.287*
		(0.096)	(0.120)	(0.090)	(0.113)	(0.044)	(0.051)	(0.112)	(0.166)
Observations		4,587	4,587	3,268	3,268	18,662	18,662	4,123	4,123

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: intmob = He/she had international mobility in the last tem years

Source: OECD, based on OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

international experience in the Northern countries. In Portugal, women have 9 % more chances of international mobility. Looking at international mobility by field of science and country we conclude that, in general, natural sciences always have more chances of having international mobility experience than doctorates from the rest of the scientific fields. The exception is for Danish doctorate holders in social sciences (58 %) and humanities (86 %) that have more chances. Time since graduation provides doctorates in all countries with fewer chances of having an international mobility experience. In Spain is 12 % less and for Belgium, Denmark and Portugal it is 6 % less. In addition, we observe that former doctorate holders have more chances in Denmark and in Belgium of having international mobility experience. In Portugal, the results are different, and the recent doctorates are 67 % more likely to have international mobility experience. This variable is not significant for Spain. If we look only at former doctorates, we observe that they have fewer chances in Belgium and are not significant for other countries.

9.7 Conclusions

In this paper we look at the career patterns of doctorate holders, comparing Portugal with Belgium, Denmark and Spain. We analyse the determinants of career choices and mobility, and factors influencing the earnings of doctorate holders by applying econometric estimates using data from the CDH-2009. Our results show that the career patterns of the four countries are very different, probably as consequence of differences in the development of the scientific and innovation system of each one of them, partially supporting the typology of Northern/Southern countries and going against the idea of certain homogeneity among European countries.

These countries present significant differences in the numbers of doctorates in the population and in the distribution of doctorate holders by employment sectors. The presence of doctorates in academia is seen as crucial for the development of science, and the presence of doctorates in firms is a means to guarantee a return on investment through the introduction of new products to the market. For this reason, throughout Europe the adequacy of doctoral training with regards to the requirements of the labor market has been extensively discussed. This issue has an effect on the expectations of doctoral students, who are increasingly reminded of the fact that an academic career is a difficult target to reach (Levecque et al. 2013). Nevertheless, the results show that even though there are different career patterns for doctorate holders, similar factors contribute significantly to these paths, namely the time since graduation, gender and field of study. Our results also shows different trends for more recent graduates, who have a higher level of precariousness in their careers, leading them to diversify their career paths, and look for alternatives in the labor market, namely seen in the increase of their mobility and propensity to start their own firms.

This analysis was only possible due with the use of the CDH micro data, which in this context becomes a crucial observation instrument for the careers of doctorate holders, bringing the ability to observe and characterize the reality and evolution of each country to this international discussion and allowing for a direct comparison between countries.

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References

Auriol L, Schaper M and Felix B (2012) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators—third edition. OECD Science, Technology and Industry working papers 2012/07. OECD Publishing. http://dx.doi.org/10.1787/5k4dnq2h4n5c-en

Becker G (1964) Human capital: a theoretical and empirical analysis, with a special reference to education. University of Chicago Press, Chicago

Enders J (2004) Research training and careers in transition: a European perspective on the many faces of the PhD, studies in continuing education, pp 419–430

European Commission (2003) Researchers in the European research area: one profession, multiple careers. COM (2003), 436 final. Commission of the European Communities, Brussels

Ferreira A, Otley D (2005) The design and use of management control systems: an extended framework for analysis. AAA Management Accounting Section 2006 Meeting Paper

Fontes M, Novais AQ, Cabral-Cardoso C (2004) Employment of young scientists in the business sector (2004), R&D management conference 2004—"Managing people and managing R&D", Sesimbra, 7–9 Julho 2004

Heitor M, Horta H, Mendonça J (2013) Developing human capital and research capacity: science policies promoting brain gain. Technol Forecast Soc Chang

Horta H (2009) Holding a post-doctoral position before becoming a faculty member: does it brings benefits for the scholarly enterprise? High Educ 58:689–721

Jesen JJ (1988) Research and teaching in the Universities of Denmark: does such an interplay really exist. High Educ 17(1):17–26

Jones O (1992) Postgraduate scientists and R&D: the role of reputation in organisational choice. R&D Manag 22(4):349–358

Kunze A (2005) The evolution of the gender wage gap. Labour Econ 12:73–97

Levecque K, Baute S, Anseel F (2013) Junior researchers in Flanders 2013: on dreams and realities. ECOOM—Centre for R&D Monitoring, Belgium

Machin S, Puhani PA (2003) Subject of degree and the gender wage differential: evidence from the UK and Germany. Econ Lett 79:393–400

Mangematin M (2000) PhD job market: professional trajectories and incentives during the PhD). Res Policy 29:741–756

Mendonça J, Madeira F, Torres Preto M (2015) Skills, teams and wages: the role of gender. IECER

Moguérou P (2005) Doctoral and postdoctoral education in science and engineering: Europe in the international competition. Eur J Educ 40(4):367–392

Neumann R, Tan K (2011) From PhD to initial employment: the doctorate in a knowledge economy. Stud High Educ 36(5):601–614

OECD (2001) Innovative people: mobility of skilled personnel in national innovation systems. OECD Publishing, Paris
Probst C, Lepori B (2008) What is a Doctorate? Changing meanings and practices in communication sciences in Switzerland. Eur J Educ 43(4):477–494
Recotillet I (2003) Availability and characteristics of survey on the destination of Doctorates recipients in OECD countries. OECD Science, Technology and Industry working paper 2003/9. OECD Publishing, Paris
Recotillet I (2007) PhD graduates with Post-doctoral qualification in the private sector: does it pay off? Labour 21(3):473–502
Senker J (1995) Tacit knowledge and models of innovation. Ind Corp Chang 4(2):425–447
Thune T (2009) Doctoral students on the university-industry interface: a review of the literature. High Educ 58:637–651
Wooldridge J (2002) Introductory econometrics, 2nd edn. South-Western, Thomson, Mason

Part III

Human Resources in Science and Technology and Their Professional Careers

Transition from School to Work of PhD Holders: The Case of France

10

Julien Calmand

10.1 Introduction

For several years, French public authorities have focused on improving the transition between school to work of PhD holders in their early working years. For over 15 years, 'Generation surveys' of the Centre d'Etudes et de Recherche sur les Qualifications (Céreq) have highlighted several stylized facts about this transition. Three years after their graduation PhD holders are relatively more likely to be unemployed than 'Grandes Ecoles' graduates and sometimes also more than university masters graduates. Then, when they enter the labor market, they give priority to careers in public and academic research instead of private R&D but above all they are reluctant to work outside of research. Finally, because of the specificity of recruitment methods in public and academic research, PhD graduates do not attain permanent positions in their first years of working life.

The results of the latest Generation survey ('Generation 2007') nuanced these results. In difficult economic conditions, while the unemployment rate remains high 3 years after graduation, it has not yet deteriorated compared to the PhD graduates who entered the labor market in 2004 and is even slightly lower than the rate of masters graduates. Moreover, results from another survey done in 2012 on the same population (PhDs graduated in 2007) show that the situation improves 5 years after the completion of the thesis: most PhD holders find a job, and moreover mainly permanent employment. These results lead us to believe that on the one hand, the deteriorating economic conditions have affected entry into the labor market of this highly skilled population less, while on the other hand, the transition process from school to labor market of PhD holders is different from other higher education graduates.

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10.2 Transition from School to Labor Market 3 Years of Graduate Doctors in 2007: Little Effect of the Crisis on Their Access to Employment

In 2007, 3 % of higher education graduates came onto the labor market with a thesis, which means around 9,000 PhD graduates. The number of doctorates has remained stable over the past 10 years. Compared to PhD holders in 2004, those from 2007 entered the labor market in tough economic times; in July 2008, the financial crisis emerged, bringing with it a sharp slowdown in economic activity (Mazari et al. 2011). However, while the entire generation has experienced depreciation in terms of school to work transition, very few PhD graduates have suffered from the decline in economic activity. While the unemployment rate 3 years after graduation for all school leavers rose by five points (19 % against 14 %) between the two generations, the leavers from higher education rose by three points (11 % against 8 %), and PhD holders' rate of unemployment remained high but stable at around 10 %. Moreover, since 2001, PhD graduates' unemployment rate is slightly lower than that of masters graduates. Several hypotheses allow us to understand this improvement. First, despite the slowdown in economic activity, gross domestic expenditure in research and development increased between 2009 and 2011 to 2.25 % of GDP (MESR 2012a), thus promoting the recruitment of researchers in the research sector (private or public) over the same period. Second, despite downsizing in the public sector that began several years ago, the number of teachers in the higher education system increased between 2007 and 2010 (MESR 2012a). Finally, policies in universities to improve PhD graduates' transition from school to work are probably paying off (Fig. 10.1).

Despite the general improvement of access conditions to the labor market in 2007, there are differences between fields of study. In 2010, the unemployment rate for PhDs in biology, social sciences and humanities (SSH), and engineering deteriorated compared to their counterparts in 2004 to 12 %, 13 % and 8 % respectively (Table 10.1). In contrast, for PhD graduates in maths/physics, and law/economics the rate fell from 8 to 3 % for the former and from 8 to 5 % for the latter. It is the same for chemists: the rate rose to an unusually high rate in 2007 (16 %) and dropped to 13 % in 2010 (Table 10.1).

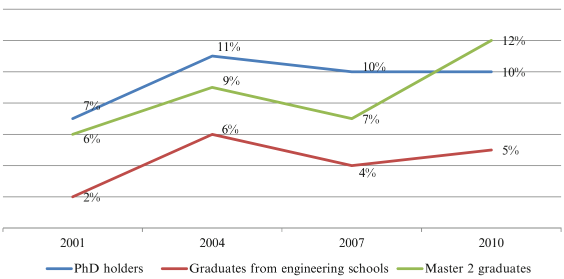

Fig. 10.1 Evolution of unemployment rate. *Source*: 'Génération 1998', 'Génération 2001', 'Génération 2004', 'Génération 2007', Céreq

Table 10.1 Indicators for PhD holders 3 years after graduation by field of science, (%)

	Unemployment rate (3 years after graduation)				Permanent contract (3 years after graduation)			
	2001	2004	2007	2010	2001	2004	2007	2010
Math, physics	5	7	8	3	14	21	22	25
Engineering	2	6	6	8	7	13	13	16
Chemistry	10	14	16	13	26	30	40	30
Biology	7	11	10	12	32	32	45	43
Law, economics	5	11	8	5	8	24	19	23
SSH	20	17	11	13	29	22	30	32

Source: 'Génération 1998', 'Génération 2001', 'Génération 2004', 'Génération 2007', Céreq

Céreq's previous work has shown that the discipline of the thesis, competition from other graduates of higher education in some specific segments of the labor market, and the conditions of achievements of the thesis are critical in the process of transition from school to work. PhD holders do not have the same access to employment opportunities upon registration of their thesis. First, a comparison of Masters graduates' unemployment rates shows the same hierarchy as for PhD holders. In fact, the unemployment rate for university graduates and PhDs in biology and Masters graduates in LSSH (Literature, Social Sciences and Humanities) are above average. Second, PhD graduates in formal science are challenged by graduates of engineering schools in recruitment in the private sector, mainly in R&D. This preference for engineers has been clearly identified by many studies on the subject (D'Agostino et al. 2009; Mason et al. 2004). In 2010, the unemployment rate of PhD holders in engineering was higher than that of engineering school graduates (8 % and 5 %). Finally, beyond the effects of specialties and PhD degrees inter-competition, conditions for completing the thesis (main place of thesis, funding, etc.) affect access to first employment.

The main place of completing the thesis is very heterogeneous across disciplines, with PhD holders in SSH reporting mainly doing their thesis outside a university or laboratory. This means that they are away from a scientific environment and thus find it harder to build their scientific networks. More than a fifth of PhD holders in SSH who graduated in 2007 achieved their thesis mainly at home compared to 3 % for the entire population. Funding of the thesis is also important. Public funding such as 'allocation de thèse' provides a salary for 3 years, thus ensuring the student has good conditions for doing their PhD. Having this type of funding is a signal: it can be seen as an investment in the future of a laboratory, and it also reduces the uncertainty of a candidate's scientific quality at the time of recruitment. The unemployment rate of PhD holders who have received public funding is three points lower than the entire population of PhD graduates. For PhD graduates, the boundaries between academia and career paths are largely porous. Thus, 70 % of doctors find employment in their first 3 months in the labor market compared to 59 % of masters graduates. In fact, most PhD graduates have been part of the labor force and acquired many professional experiences during their training. Few people complete their degrees without ever having been employed. Usually, they have a succession of regular jobs while studying such as teachers in secondary school, research assistants, or even jobs in a company. These jobs, often precarious, continue after graduation for most; only 39 % of PhD holders have experienced a single job sequence in the first 3 years of their working life.

10.3 Job Instability 3 Years After Graduation

Three years after completing the thesis, nearly half of PhD holders are working in public and academic research. Except for engineering where the proportion of PhD graduates working in R&D is around 40 %, a job in academia is the most popular for all disciplines. Again, the conditions in which the thesis is completed play a role in both access to public research (grants, publications in peer-reviewed journals, etc.) and to private research (CIFRE funding,[1] public cooperation/private project search, etc.). The discipline of the thesis is also critical as, for example, R&D in companies mainly concerns doctors in the natural or formal sciences. Thus in these disciplines, 27 % of PhD holders are working in R&D 3 years after graduation. If that figure seems low, it should be remembered that in France access to private research is not generally open to PhD holders. For example, in 2009 54 % of researchers in companies have an engineering degree, 15 % have a M2 degree and only 13 % have a PhD (MESR, Etats de l'Ensignement Supérieur et de la Recherche, 2012b). Jobs outside research activities represent an excellent opportunity for PhDs in SSH since 47 % of them work in this sector 3 years after graduation.

The study of PhD holders' trajectories in their first 3 years of working life points to difficulties in accessing permanent employment. These problems are not specific to French PhD holders; they are also present in many OECD countries (Enders 2002; Bonnal and Giret 2009; Ma and Stephan 2005). In their first job, 70 % of PhD graduates in 2007 are employed on fixed terms compared to 66 % for those who graduated in 2004. Three years after graduation, 30 % of PhD holders have still not attained permanent employment, with PhDs in biology (43 %) and SSH (32 %) the most often in this situation.

This high proportion of non-stable jobs is mainly explained by conditions of employment in public and academic research where 40 % of PhD holders have a fixed term contract compared to 21 % for the private R&D sector. In public or academic research, access to permanent positions responds to very specific mechanisms. In some fields, such as biology, it is mandatory to acquire additional research experience to be eligible for permanent jobs in academic research. These work experiences (called 'post-docs') allow doctors to acquire additional expertise in research and gain new valuable skills. They are also necessary for peers to observe the qualities of future scientists over a longer period while considering the possibilities for employing them on a more permanent basis. In addition, the

[1] CIFRE: Convention Industrielle de Formation par la REcherche.

reconstruction of employment in the public research sector is another explanation; the use of non-permanent employment has greatly increased here. While the number of teachers increased by 6 % between 2004 and 2012, and those of lecturers increased by 10 %, non-permanent teachers increased in number by 22 %, which represents 27 % of all teachers in higher education in 2012. Beyond the differences in job contracts, the survey also reveals sectorial wages differentials. The PhD graduates working in private R&D are the highest paid 3 years after graduation (over 2,400 euros). In public and academic research, the monthly wage is 2,100 euros. PhD graduates who are working in non-research sectors earn about 2,000 euros net per month. In the private sector outside research, the median net monthly wages of doctors are only 100 euros higher than masters graduates employed in this sector at the same time.

10.4 PhD Holders' Early Careers: Deferred Access to Stable Employment

A survey funded by the DGESIP[2]/DGRI[3] and conducted between September 2012 and March 2013 allowed us to study the career paths of PhD holders who graduated in 2007 five years after completing their thesis. Initial results show that the situation of PhD graduates improves markedly over time. Between 2010 and 2012, the employment rate of PhD graduates in 2007 increased from 88 to 94 %. PhD holders in biology have the lowest employment rate (less than 90 %) in 2012. Five years after graduation, the PhD graduates' median net wages increased on average by 10 % in constant euros since 2010 which means 2,500 euros in 2012. The structure of jobs has changed very little between the two surveys; however the share of PhD graduates working in research (public or private) has increased. Instability in employment decreased between 2010 and 2012 from 30 to 14 %.

Sectorial disparities in employment conditions are still visible in doctorate holders' early careers. Five years after graduation, the net monthly wages of PhD holders who are working outside research (public or private) does not exceed 2,000 euros. In private R&D, monthly salaries are around 2,800 euros and in public and academic research they amount to more than 2,500 euros. Ultimately, it is the young people who are working in research and particularly in private R&D that experienced the largest increases in salaries. Moreover, wage differentials between research versus non-research sectors grew between 2010 and 2012. In R&D, a quarter of PhD graduates earn more than 3,200 euros per month.

Beyond the salary differences, PhD holders not working on research activities are more often dissatisfied with their work situation. In these sectors, they consider themselves lower paid: this is true for 56 % of those employed in the public sector excluding research and half of those working in the non-research private sector. In comparison, only 41 % of PhD graduates in public and academic research and 29 %

[2] DGESIP: Direction Générale de l'Enseignement Supérieur et de l'Insertion Professionnelle.

[3] DGRI: Direction Générale de la Recherche et de l'Innovation.

Table 10.2 Indicators for PhD holders 5 years after graduation, 2012

	Academic and public research	Public sector non-research	Private R&D	Private non-research
Share of the population (%)	52	10	25	13
Permanent contract (%)	15	35	10	8
Net monthly earnings	2,452	2,000	2,815	2,000
Employed below stated level of competences (%)	16	64	21	59

Source: Survey 5 years after graduation of PhD holders who graduated in 2007, Céreq

in R&D feel that way. Those working in private R&D consider themselves better paid (71 %). Dissatisfaction amongst doctorate holders also results in a desire to change jobs. In 2012, more than a fifth of PhD graduates working in non-research sectors say that they are looking for another job, compared to only 14 % in academic research and 12 % in R&D. One of the reasons for dissatisfaction is the fact that PhD holders believe that they are employed below their skill level (59 % in the private and 64 % in the public sector). These figures contrast with those engaged in research, where only 16 % of PhD holders (public sector) and 21 % (private sector) stated that they feel employed below their skill level (Table 10.2).

10.5 PhD Holders' Early Career Difficulties: A Problem of Skills?

One aspect of the survey developed in 2012 focuses on the skills of PhD holders. Analysis of skills is rarely addressed in studies of the early careers of PhD graduates. The objectives of this analysis are to answer the following questions: do PhD graduates have the skills needed by jobs in various segments of the labor market? Does their doctoral education provide them with the skills which are necessary on the labor market? As we have pointed out (Calmand et al. 2009), research using human capital theory neglects the concept of competence. Yet some analyses have attempted to re-introduce this concept (Hartog 2000; Allen and van der Velden 2005; Heijke et al. 2003; Paul and Suleman 2004) by including works inspired by sociologists, psychologists and specialists in education. However, there is not yet any consensus on either the definition used or their measurement (Loo and Semeijn 2004). To measure skills in this survey, we used the method of self-assessment of skills used on the job and skills acquired during the thesis. One limitation of this approach is that it leaves room for individuals' subjectivity: it is not impossible that some individual skills measured are related to social judgments, cultural or individual values (Allen and van der Velden 2005). However, the advantage of this method is that it enables us to compare skills on relatively large samples that cannot be done with analyses based on qualitative interviews. We have chosen to describe seven competences:

- Specific scientific expertise to own field of study;
- Communication skills;
- Interpersonal skills;

- Management skills;
- Project management skills;
- Adaptation skills;
- Innovation capacity.

The choice of these skills is not trivial. The idea is to combine related specific skills of PhD graduates and more general skills used in the labor market. The specificity of PhD holders are based on skills related to research activities and thus their ability to use their scientific knowledge and also to innovate. PhD graduates are a highly skilled labor force and work to take a central role in the knowledge economy (Foray 2009). In fact, they are expected to have the capacity to adapt to work and hold top positions in organizations. Several skills introduced in the questionnaire concern the ability to cope with change within the company (interpersonal skills, communication skills), but also the capability to assume managerial positions (management skills, team leadership, and project management). To measure the skills of doctors, we asked two questions:

- 'On a scale of 1–5, can you evaluate the use of these skills in your current job?'
- 'On a scale of 1–5, can you assess the development of the following skills during your thesis?'

The scale used to measure the level of skills is a Likert scale, with 1 being 'very low' and 5 'very high.'

a) Skills acquired during the thesis

We will first detail the results from our survey about skills acquired during the thesis. Regarding all PhD graduates, these skills can be classified as follows:

- specific scientific expertise to the field of study (mean 4.34);
- adaptation skills (mean 3.82);
- innovation skills (mean 3.77);
- communication skills (mean 3.14);
- interpersonal skills (mean 3.03);
- project management skills (mean 2.72);
- management skills (mean 1.92).

The results show disparities by discipline in the acquisition of skills. However, a common thread emerges: the adaptability and innovation are strong points of doctoral training. PhD holders in biology and engineering have relatively higher levels of these skills than those in other disciplines. PhD graduates in SSH perceive that they have lower level of skills. Innovation capabilities are relatively strong for PhDs in biology and engineering, but lower for graduates of SSH. Regarding the specific scientific expertise to the field of theory, 85 % of PhD holders reported that they had a score of 'greater than or equal to 4' on a scale of 5. The young people from SSH certified most often that they had the maximum level of 5 in this type of skill (65 %). Communication skills seem to be neither a strength nor a weakness of doctoral training. In formal sciences, PhD holders report having these skills at around the average level, while doctors in SSH seem to be more prone to declare that they do not have that skill. Interpersonal skills are more developed by PhD graduates in biology than in other disciplines. Those from maths/physics and chemistry as well as SSH are most likely to report the lowest level for this skill.

Two skills are overall at very low levels: project management and team management. For skills in project management, only PhD holders in biology report an average level equal to 3. In all other disciplines the level was below 3. Doctors in SSH have the lowest level in project management skills, with 51 % of SSH PhD graduates saying that they had a level below 3. Management skills thus appear to represent a weak point of the doctoral training level. Across all disciplines, the average is less than 3. Nearly 80 % of doctoral holders say that the SSH discipline is below 3 in this kind of skill.

In what follows, we seek to estimate the determinants of skills during doctoral training. To estimate the probability of having a high level of skills acquired during doctoral training, we use 'ordered logit' models to obtain estimates of the explanatory factors in the degree of competence gained (Calmand and Recotillet 2013). Table 10.3 in the annex presents the key results. The main assumption of the model is based on the link between skills acquired in doctoral training and conditions for progress of the thesis. Demographics variables are introduced as control factors. Seven different models corresponding to the seven skills were estimated separately. The results of the different models conclude too small differences in terms of skills. Finally, the discipline is a small and significant explanatory factor. Only PhD holders from SSH have lower odds of having high levels for skills in communication, leadership and team management, although the results are not significant. Completing a thesis in 3 years (instead of 4 or 5 years) increases the competence in specific scientific expertise in the own field, interpersonal skills, project management and communication skills. PhD holders who completed their thesis at home have a higher probability of having low levels in soft skills and management team leadership.

b) The skills required in employment

Our study also allows us to assess the skills needed in employment. It is assumed that the level of expertise required is directly related to the type of job in which doctorate holders are employed. The hierarchy of skills is as follows:

- adaptation skills (mean 4.22);
- interpersonal skills (mean 4.07);
- specific scientific expertise to the field of study (mean 3.85);
- communication skills (mean 3.84);
- innovation skills (mean 3.78);
- project management skills (mean 3.49);
- management skills (average 2.81).

The skills most needed in employment are adaptation skills. In private research, more than 90 % of PhD graduates declare that this skill is strongly required in their jobs. Interpersonal skills are highly cited among the doctors working in the public sector, whether related to research or not (levels 4 and 5). Regarding the specific scientific expertise to the field of study, PhD graduates who are working outside research have levels below those employed in private or public research. 60 % of PhD holders who are working in research reported a high level (4 and 5), while for those not engaged in research the rate does not exceed one third. PhD graduates working in academic or public research report a higher skill level for specific scientific expertise than those employed in private research. Required communication skills are quite high in public and academic research and in the non-research private sector; however, in general, the distribution between sectors is very close. As expected, innovation capabilities are in high demand in both public and private research: 70 % of PhD holders reported a level higher than 3. However, in jobs outside research, innovation capabilities are not required. For example, in the non-research public sector, only 41 % of PhD holders reported a high level in innovation capabilities. Project management skills are widely required in private research where 66 % of graduates report a high level. PhD graduates working in the public sector outside research declared the least need of competences in project management. Overall, skills of management and team leadership appear to be the least required in non-research public sector.

c) Deficit/surplus of competences

The main interest in assessing the skills needed in employment and the skills acquired in doctoral training lies in putting them in perspective. This allows us to evaluate the deficit and surplus of skills. The deficit/surplus is the balance between required competences in a job and acquired competences. The following chart is used to assess competence gaps by discipline of the thesis and by industry (Fig. 10.2). Less than 30 % of PhDs reported a deficit of scientific expertise in the area of their thesis specialisation. PhD holders in biology are most likely to meet a deficit in their area of expertise. The largest recorded losses relate to interpersonal skills, project management skills, and team leadership and communication, where over 50 % of PhD graduates reported a lack of skills. Except for specific scientific expertise in the field of study and innovation, PhD holders in SSH declared the biggest skills deficit. In terms of employment sector, skills gaps are less important in public and academic research.

To analyse the skills surplus and deficit, we carried out some econometric models (Calmand and Recotillet 2013). Table 10.4 in the annex presents the results. PhD holders in engineering sciences have a higher probability of knowing not only a surplus in specific scientific skills in their field of study but also in innovation capacity. Conversely, graduates in SSH have a relatively high probability of experiencing a skills gap in four areas: communication skills, interpersonal skills, management skills, and skills in project management. Compared with public and academic research, PhD graduates not working in this sector are more likely to experience a surplus of specific scientific skills in their field of study. In the non-research public sector, the probability of having a surplus of skills is much more important than in public research. PhD holders who are working in the former sector have a surplus of management skills, project

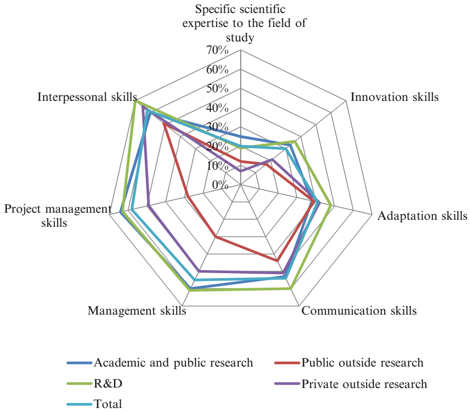

Fig. 10.2 Deficit of competences in jobs. *Source*: Survey 5 years after graduation of PhD holders who graduated in 2007, Céreq

management, adaptation skills and capacity for innovation. In private research, PhD graduates have a lack of interpersonal skills, management leadership and adaptability. In the non-research private sector, graduates have a higher probability of having a lack of competences in innovative capacities and interpersonal skills. Finally, PhD holders recorded a deficit of skills when they work in management positions. This result is very significant for four of the seven skills: interpersonal skills, management skills and leadership, communication skills, and project management competences. PhD graduates working in the public, non-research sector suffer from a downgrade in terms of skills.

10.6 Conclusion

Surveys from Céreq on PhD holders' transition from school to work show those with a PhD have great difficulties compared to other graduates from higher education. Even if their difficulties have not increased with the recent economic crisis, PhD holders have difficulties in finding a permanent job in their first 3 years of working life. Five years after graduation these problems are resolved, with the majority finding a permanent job in the labor market. However, there are disparities in terms of satisfaction and earnings between those who are working in research and those outside research. These differences increased with time, with PhD holders employed outside research less satisfied and lower paid than those working in research. As an explanation, graduates not working in research 5 years after graduation declare themselves to be employed below their level of competences. Analyses of skills show that PhD graduates not employed in research have a higher probability of having a surplus of competences.

Annex

Table 10.3 Probability of having a high level of acquired competences, Ordered logit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Specific scientific expertise to own field of study	Communication skills	Interpersonal skills	Management skills	Project management skills	Adaptation skills	Innovation skills
Man	−0.235	−0.0522	−0.292**	−0.0469	0.148	−0.340**	0.160
	(−1.46)	(−0.35)	(−1.99)	(−0.31)	(1.02)	(−2.27)	(1.08)
Foreign parents	0.0493	−0.0664	−0.165	0.355	0.288	0.884**	0.321
	(0.14)	(−0.20)	(−0.52)	(1.08)	(0.89)	(2.54)	(0.96)
Father occupation: professional	0.122	0.0381	0.0362	−0.412***	−0.199	0.0778	−0.0912
	(0.79)	(0.27)	(0.26)	(−2.75)	(−1.41)	(0.54)	(−0.64)
Field of study (ref: Math/physics/chemistry)							
Biology	0.0445	−0.0213	0.141	0.193	0.374*	0.284	−0.143
	(0.20)	(−0.10)	(0.67)	(0.90)	(1.79)	(1.32)	(−0.67)
SSH, economics and law	0.210	−0.437*	−0.308	−0.417*	−0.320	−0.134	0.0142
	(0.85)	(−1.89)	(−1.37)	(−1.74)	(−1.45)	(−0.59)	(0.06)
Engineering	−0.105	−0.286	−0.210	−0.0610	0.0313	0.0784	0.373*
	(−0.45)	(−1.34)	(−0.96)	(−0.27)	(0.15)	(0.36)	(1.70)
Thesis completion in 3 years	0.428**	0.434***	0.284*	0.263	0.271*	0.0713	−0.125
	(2.44)	(2.66)	(1.78)	(1.61)	(1.71)	(0.44)	(−0.79)
Have not done a postdoctoral experience	0.0225	−0.304*	−0.0996	−0.0417	0.207	0.0319	0.0589
	(0.13)	(−1.89)	(−0.62)	(−0.25)	(1.30)	(0.20)	(0.36)
Search location (ref: University)							
Public organization	−0.0207	−0.131	0.161	−0.317	0.0608	−0.199	−0.0713
	(−0.09)	(−0.63)	(0.77)	(−1.45)	(0.29)	(−0.92)	(−0.33)
Other	0.131	−0.169	−0.431**	−0.418*	−0.0283	−0.119	−0.285
	(0.58)	(−0.84)	(−2.12)	(−1.91)	(−0.14)	(−0.57)	(−1.36)
Articles during PhD	0.0784	0.143	0.0705	0.0179	−0.207	−0.0955	−0.0743
	(0.44)	(0.86)	(0.42)	(0.10)	(−1.23)	(−0.56)	(−0.44)

(continued)

Table 10.3 (continued)

	(1) Specific scientific expertise to own field of study	(2) Communication skills	(3) Interpersonal skills	(4) Management skills	(5) Project management skills	(6) Adaptation skills	(7) Innovation skills
Label lab (ref: University)							
CNRS	−0.157	0.215	0.0470	0.272	0.0394	0.136	−0.000421
	(−0.76)	(1.12)	(0.25)	(1.35)	(0.21)	(0.71)	(−0.00)
Other	−0.0314	0.285	0.102	0.395	0.0795	0.0225	−0.133
	(−0.11)	(1.10)	(0.40)	(1.44)	(0.31)	(0.09)	(−0.52)
Public funding	−0.0463	0.113	0.0334	0.139	−0.0124	−0.0173	0.00868
	(−0.28)	(0.75)	(0.22)	(0.88)	(−0.08)	(−0.11)	(0.06)
M2: Engineering school	−0.277	−0.0967	0.142	−0.0693	−0.351*	−0.217	0.0794
	(−1.39)	(−0.52)	(0.76)	(−0.36)	(−1.94)	(−1.16)	(0.43)
Professional expectation (ref: Academic research)							
R&D	−0.305	0.0647	0.00822	−0.160	−0.119	0.319	−0.194
	(−1.26)	(0.28)	(0.04)	(−0.68)	(−0.53)	(1.39)	(−0.85)
Other	−0.489	−0.120	−0.135	−0.377	−0.0771	0.286	−0.163
	(−1.61)	(−0.40)	(−0.46)	(−1.16)	(−0.25)	(0.94)	(−0.54)
Qualification to CNU	0.497***	0.0381	0.125	−0.150	−0.0211	0.0214	0.152
	(2.62)	(0.22)	(0.71)	(−0.83)	(−0.12)	(0.12)	(0.86)
cut1 Constant	−3.530***	−2.199***	−2.345***	−0.297	−1.344***	−3.692***	−3.597***
	(−8.39)	(−6.45)	(−6.84)	(−0.86)	(−4.06)	(−9.20)	(−9.01)
cut2 Constant	−2.741***	−1.102***	−0.971***	1.017***	−0.287	−2.312***	−1.942***
	(−7.18)	(−3.36)	(−2.97)	(2.92)	(−0.88)	(−6.63)	(−5.70)
cut3 Constant	−1.610***	0.538*	0.639**	2.149***	0.885***	−0.756**	−0.555*
	(−4.49)	(1.66)	(1.97)	(5.97)	(2.70)	(−2.27)	(−1.67)
cut4 Constant	0.0190	2.273***	2.172***	3.467***	2.412***	0.907***	1.150***
	(0.05)	(6.66)	(6.41)	(8.44)	(6.99)	(2.72)	(3.44)
Observations	672	672	672	672	672	672	672

t statistics in parentheses *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

Source: 'Génération 2010, Interrogation en 2013 des sortants de 2010', Céreq, 2014

Table 10.4 Probability of knowing a surplus/deficit of competences, Ordered logit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Specific scientific expertise to own field of study	Communication skills	Interpersonal skills	Management skills	Project management skills	Adaptation skills	Innovation skills
Number of employment (months)	−0.00880	0.0280*	0.0144	0.0177	0.000722	0.000740	0.0155
	(−0.58)	(1.94)	(0.98)	(1.21)	(0.05)	(0.05)	(1.04)
Number of months (outside job)	−0.0131	0.0109	−0.00778	0.00138	−0.0168	−0.0120	0.0104
	(−0.76)	(0.66)	(−0.47)	(0.08)	(−1.02)	(−0.71)	(0.60)
Man	0.295*	−0.357**	−0.353**	−0.364**	−0.389**	−0.0711	0.0870
	(1.82)	(−2.32)	(−2.28)	(−2.33)	(−2.55)	(−0.45)	(0.55)
Foreign parents	−0.424	0.103	−0.207	−0.236	−0.427	−0.330	0.0877
	(−1.24)	(0.29)	(−0.59)	(−0.72)	(−1.23)	(−0.97)	(0.25)
Father occupation: professional	−0.246	−0.186	−0.101	0.0738	−0.160	−0.183	−0.0392
Foreign parents	(−1.63)	(−1.27)	(−0.69)	(0.50)	(−1.11)	(−1.23)	(−0.27)
Field of study (ref: Math/physics/chemistry)							
Biology	−0.620***	−0.0320	0.0567	0.0463	−0.163	−0.0932	−0.694***
	(−2.69)	(−0.14)	(0.25)	(0.21)	(−0.73)	(−0.41)	(−3.02)
SSH, Economics and Law	0.00665	0.0593	0.133	0.0572	0.120	−0.0535	−0.291
	(0.03)	(0.28)	(0.63)	(0.26)	(0.57)	(−0.25)	(−1.31)
Engineering	−0.320	0.917***	0.882***	0.810***	0.520**	0.305	−0.249
	(−1.51)	(4.42)	(4.21)	(3.86)	(2.55)	(1.44)	(−1.20)
Part-time job	0.0417	−0.235	−0.236	−0.606	−0.285	0.178	0.309
	(0.10)	(−0.58)	(−0.63)	(−1.51)	(−0.72)	(0.45)	(0.75)

(continued)

Table 10.4 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Specific scientific expertise to own field of study	Communication skills	Interpersonal skills	Management skills	Project management skills	Adaptation skills	Innovation skills
Job occupied in 2012 (ref: Academic)							
Public outside research	−1.802***	−0.400	−0.275	−0.791**	−1.407***	−0.643*	−1.276***
	(−4.84)	(−1.11)	(−0.77)	(−2.20)	(−4.05)	(−1.80)	(−3.42)
R&D	−0.628***	0.156	0.427*	0.518**	0.291	0.419*	−0.0141
	(−2.66)	(0.68)	(1.92)	(2.30)	(1.35)	(1.86)	(−0.06)
Private outside research	−1.870***	0.185	0.554*	0.281	−0.513	0.203	−0.698**
	(−5.66)	(0.56)	(1.73)	(0.85)	(−1.60)	(0.62)	(−2.08)
Live in Paris region	−0.235	−0.220	0.138	−0.164	−0.0512	−0.312	−0.414**
	(−1.18)	(−1.13)	(0.72)	(−0.84)	(−0.27)	(−1.56)	(−2.11)
Supervise other	−0.0459	0.487***	0.432***	1.763***	0.57***	−0.0209	0.0975
	(−0.29)	(3.17)	(2.81)	(10.46)	(3.76)	(−0.13)	(0.62)
Work contract (ref: Unlimited)							
Limited	0.0356	−0.232	0.0544	−0.173	0.260	0.340	0.282
	(0.15)	(−1.01)	(0.23)	(−0.74)	(1.15)	(1.45)	(1.20)
Self worker	0.799	−0.307	−0.529	−0.521	−0.519	−0.0649	−0.168
	(1.50)	(−0.56)	(−1.01)	(−1.03)	(−1.00)	(−0.12)	(−0.34)
M2: Engineering school	0.428**	0.244	−0.0315	0.116	0.304	0.0289	−0.0356
	(2.18)	(1.31)	(−0.17)	(0.62)	(1.63)	(0.15)	(−0.19)
Work in own field of study	0.987***	0.0144	−0.0921	−0.0162	−0.0938	−0.453**	−0.194
	(4.94)	(0.08)	(−0.49)	(−0.09)	(−0.50)	(−2.41)	(−1.01)
Employed below his own level of competences	−0.909***	−0.246	−0.142	−0.360*	−0.304	−0.0754	−0.411**
	(−4.50)	(−1.28)	(−0.73)	(−1.86)	(−1.59)	(−0.39)	(−2.08)

Links between job and professional expectations	0.0203	−0.259	−0.238	0.116	0.143	0.207	0.252
	(0.09)	(−1.15)	(−1.10)	(0.53)	(0.67)	(0.94)	(1.10)
cut1	−4.375***	−4.926***	−3.581***	−3.569***	−5.808***	−6.127***	−4.621***
Constant	(−4.04)	(−3.45)	(−3.28)	(−3.16)	(−4.92)	(−4.82)	(−4.02)
cut2	−3.271***	−3.309***	−1.736*	−2.421**	−4.675***	−3.897***	−3.235***
Constant	(−3.05)	(−2.98)	(−1.67)	(−2.27)	(−4.33)	(−3.60)	(−2.99)
cut3	−2.490**	−1.785*	0.402	−0.766	−3.302***	−1.960*	−2.032*
Constant	(−2.33)	(−1.71)	(0.39)	(−0.74)	(−3.18)	(−1.85)	(−1.91)
cut4	−1.561	−0.277	1.719*	1.376	−1.874*	0.149	−0.620
Constant	(−1.46)	(−0.27)	(1.66)	(1.33)	(−1.83)	(0.14)	(−0.59)
cut5	1.043	1.556	3.145***	2.700***	−0.412	1.585	1.372
Constant	(0.98)	(1.51)	(3.01)	(2.60)	(−0.40)	(1.50)	(1.29)
cut6	2.690**	2.869***	4.720***	3.887***	0.799	2.917***	2.824***
Constant	(2.51)	(2.78)	(4.41)	(3.72)	(0.78)	(2.72)	(2.65)
cut7	4.156***	4.316***		4.975***	1.891*	4.868***	4.403***
Constant	(3.72)	(4.16)		(4.72)	(1.85)	(4.17)	(4.03)
cut8	4.854***	5.894***			3.221***		7.065***
Constant	(4.14)	(5.50)			(3.10)		(4.85)
Observations	639	639	639	639	639	639	639

t statistics in parentheses *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$
Source: 'Génération 2010, Interrogation en 2013 des sortants de 2010', Céreq, 2014

References

Allen J, van der Velden R (2005) The flexible professional in the knowledge society: conceptual framework of the REFLEX project, REFLEX working paper 1. Tech rep. ROA, Maastricht

Bonnal L, Giret J-F (2009) La stabilisation des jeunes docteurs sur le marché de l'emploi académique. Revue d'Economie Politique 119:373–400

Calmand J, Recotillet I (2013) L'insertion des docteurs—Interrogation en 2012 des docteurs diplômés en 2007. Net.doc, 115

Calmand J, Giret J-F, Guégnard C (2009) Why Grande Écoles are so valued? Some arguments using the REFLEX data. 17th annual workshop, Transitions In Youth (TIY)

D'Agostino A, Calmand J, Moncel N, Sulzer E, Lozier F (2009) Intégrer l'entreprise privée avec un doctorat. L'exemple de la branche ingénierie, informatique, études et conseil. Bref, 268

Enders J (2002) Serving many masters: the PhD on the labour market, the everlasting need of inequality, and the premature death of Humboldt. High Educ 44(3/4):493–517

Foray D (2009) L'économie de la connaissance. Éditions La Découverte, Paris

Hartog J (2000) Over-education and earnings: where are we, where should we go? Econ Educ Rev 19(2):131–147

Heijke H, Meng C, Ramaekers G (2003) An investigation into the role of human capital competences and their pay-off. (001)

Loo J, Semeijn J (2004) Defining and measuring competences: an application to graduate surveys. Qual Quant 38:331–349

Ma J, Stephan P (2005) The increased frequency and duration of the postdoctorate career stage. Am Econ Rev 95(2):71–75

Mason G, Beltramo J-P, Paul J-J (2004) External knowledge sourcing in different national settings: a comparison of electronics establishments in Britain and France. Res Policy 33 (1):53–72

Mazari Z, Meyer V, Ryk F, Winnicki P (2011) Le diplôme: un atout gagnant pour les jeunes face à la crise. Bref, 283

MESR (2012a) L'état de l'enseignement supérieur et de la recherche. (MESR, Éd.) MESR

MESR (2012b) Etats de l'Ensignement Supérieur et de la Recherche

Paul J-J, Suleman F (2004) Rewarding human capital and competencies: an analysis of the banking sector in Portugal. SPIE

11 Russian Researchers: Professional Values, Remuneration and Attitudes to Science Policy

Leonid Gokhberg, Galina Kitova, and Tatiana Kuznetsova

11.1 Introduction

Improving human potential in R&D and increasing its performance are key to the development of human capital globally. The topic of R&D personnel has been on Russia's S&T policy agenda for roughly 20 years. There are numerous reasons for the persistence and even aggravation of existing problems. In the 1990s, after the fall of the Soviet Union, the R&D sector went through a serious economic crisis. Amid negative changes in the internal and external environment there was a sharp drop in the provision of resources for research, reducing the productivity of research and experimental activity and its contribution to the development of the economy and society as a whole (Gokhberg et al. 2011; Kuznetsova 2013). Global positions in this area have also deteriorated. The level of publication activity in the country shifted from 3rd place during the Soviet era to 6th place at the start of the 1990s, and to 15th place in 2013. In the period 2000–2013 the proportion of publications by Russian authors in scientific journals indexed by Web of Science decreased from 3.22 to 1.92 % (Brazil—2.48 %, Japan—5.27 %, USA—24.85 %). However, in terms of patent activity (in 2013 28,765 patent applications filed in Russia by residents, 44,914—by residents and non-residents), Russia occupies the sixth position globally, but based on the number of applications per one million of the population (240.0)—it is only at the end of the top 30 globally.[1]

The size and other characteristics of research personnel serve as a fair reflection of the situation in the R&D sector and science and technology (S&T) policy and an

[1] Here and below (unless otherwise stated) all figures have been derived from (HSE 2006, 2009, 2014a, b).

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overall assessment of the effectiveness of regulation in this area. In absolute terms, Russia continues to occupy a leading position in the world after the US, Japan and China based on R&D personnel numbers. However, Russia ranks 21st globally in terms of the number of people engaged in R&D per 10,000 employees, and 29th in terms of researchers.

With this, there are still significant imbalances in the structure of R&D personnel, which have become almost chronic. Even in Soviet times, an extensive R&D sector model was characterized by an increase in the number of R&D organizations and the number of researchers working on new areas. The consequence of this approach was that the structure of R&D personnel became significantly distorted towards workers not so much involved in the research process, but in supporting the organization itself. After the collapse of the Soviet Union, the network of research organizations at first started to shrink quite dramatically, but later stabilized at 3,500–3,600. In 2013, the number of researchers approached 370,000, which accounted for 50.8 % of R&D personnel (technicians serving the scientific process accounted for 8.4 % and support and auxiliary staff for 40.8 %). Given the level of qualification of the latter, 29.6 % of all R&D personnel consequently do not have a university diploma.

Since the 1990s, the number of R&D personnel has reduced by 2.7[2] times. The biggest decline occurred in 1991–1993 and was linked to the unregulated outflow of scientists both into other fields and abroad, including due to the lack of significant institutional changes in the field of S&T. In the period 1991–2000 the population of researchers reduced by 2.1 times. Later, in 2000–2013, this process slowed somewhat, with a decline of 15.4 %, which can be accounted for by the substantial growth in budgetary spending on R&D (since the mid-2000s) and a number of government measures to support research.[3]

As such, the current state of the corpus of Russian researchers (including their professional preferences and values, attitudes towards policy instruments and other characteristics) cannot be considered outside of its historical context, which is linked to the landslide decline in researcher numbers in the 1990s and the many years spent clinging on to Russia's traditional research model.

One of the key characteristics of this model is the dominance of the state. In 2013, the proportion of state ownership was 71.8 % of all R&D performing organizations (including nearly 48 % which were institutions administered by government agencies and 11.8 % which were state corporations and large state-

[2] Growth in the number of research personnel began to fall in the USSR at the start of the 1980s. Since 1985, a trend of net reduction started to take hold. This was linked to ineffective motivation for the work of scientists, inadequate social protection, the decline in the prestige of research activity, an outflow of some employees of the most productive age groups from the R&D sector, and ageing of research personnel, among other issues (Gokhberg 1990, p. 64, 65, 125).

[3] These include encouraging collaboration between universities and industry, attracting leading scientists from abroad to universities and research centers, reorganizing state academies of science, developing the system of public S&T and innovation foundations, etc.

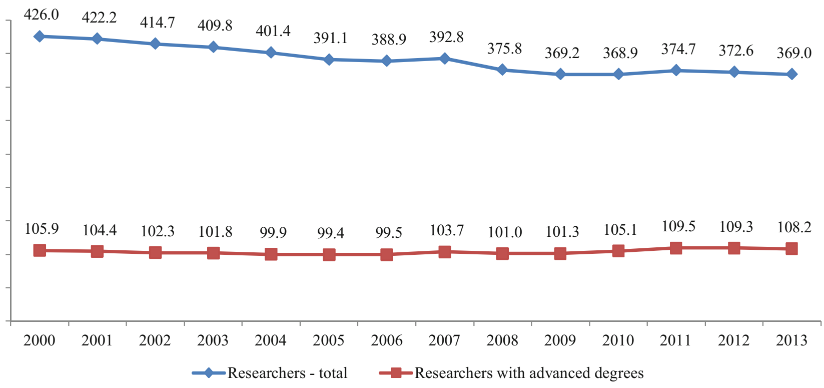


Fig. 11.1 Number of researchers in the period 2000–2013 (thousands). *Sources*: HSE (2014a, b)

owned companies). These data point to the strict reliance of the Russian R&D sector and its human resources in particular on government S&T policy.

The decline in the number of researchers in the period 2000–2013 was accompanied by a slight improvement in their qualifications (an increase in the proportion of researchers with advanced degrees from 24.9 to 29.3 %) caused by a relative stabilization in trends for this category of employees (Fig. 11.1).

The importance of the minor (on first glance) reduction in 2013 of the average researcher age to 47 years (48–49 years in 2000s) is linked not so much with the inertia of this indicator, but rather the long-term presence of the task of "rejuvenating" research personnel on the agenda of Russia's S&T policy. The overall number and structural characteristics of researchers in the period 2000–2013 changed against the backdrop of significant growth in budgetary allocations for civil S&T (an increase of 25 times at current prices and 4.8 in fixed prices).[4]

These changes, both positive and negative, referred to specific age cohorts (Table 11.1).

One of the most influential reasons for the negative trends in researcher numbers and work productivity is the lack of *interest (motivation) in enhancing the effectiveness of their activities*. It is also worth noting the insufficient level of pay (compared with other sectors of the economy and leading foreign countries), the ever low prestige of the profession in society, and the lack of incentives and conditions conducive to successful activity on the level of organizations, research groups and individual scientists.

Attitudes to science and related activities in Russia are remarkable for one noticeable characteristic. Like education, for many decades it has been a form of personal self-identification, a fetish and an object of personal interest at various

[4] In terms of their value, in 2013 Russia was on a par with Germany and Japan, trailing only the US and China (HSE 2014b, p. 32).

Table 11.1 Shifts in the age structure of researchers' population in Russia, 2010–2013

Improvements in the age structure of researchers	Negative trends
The proportion of relatively young researchers (up to 40 years) surpassed 40 % of the total number of researchers and stabilized at this level.	About a quarter of Russian researchers are above the formal retirement age.
Absolute growth in two groups: researchers under 30 and the 30–39 year-old group (10.6 % and 20 % respectively).	The proportion of researchers over 70 years is fluctuating around the 9 % mark.
There has been some stabilization in the 60–69 year-old group.	A stable decline in the creative age groups: 40–49 and 50–59 year-olds; down by 7.3 % and 8 %, respectively, during 2010–2013.

Source: National Research University Higher School of Economics

levels (Gokhberg et al. 2010, 2011). Today, the development of human potential in the R&D sector is taking place amid the ever more stringent requirements of the state and society in terms of the level and quality of research results and their contribution to the competitiveness of the national economy and improving social welfare. Proof of this are the decisions adopted by the President and Government of the Russian Federation in 2012–2013, according to which certain target developmental indicators were defined for this area for the period up to 2018 and a framework was set out to regularly evaluate the effectiveness of the activities undertaken by research institutions and universities and to use the results in institutional reforms in the public R&D sector and broader S&T policies.

11.2 Specialized Surveys of Researchers: Methodological Issues

In Russia the surge of interest in sociological studies of human and other aspects of R&D sector development came about in the first half of the 1990s, due mainly to questions of scientific mobility and brain-drain in particular.[5] The findings complemented official statistics and made it possible to diagnose current problems and trends linked to the specific nature of research activity and opportunities to increase productivity (Gokhberg 2003, pp. 298–371). Subsequently, the emphasis shifted to studying the trajectory of career scientists, their professional values and preferences, wages, etc. This reflected a change not only in actual personnel problems in the Russian R&D sector, but also in the S&T policy agenda.[6] There

[5] Cf., for example: Gokhberg and Mindeli (1996), Gokhberg and Nekipelova (2002), Zaionchkovskaya and Azrael (1994), Kitova et al. (1995), Kitova and Kuznetsova (1997), Zaionchkovskaya (2004), Chepurenko and Gokhberg (2005), Dezhina (2014), and others.

[6] An example of this is the political decisions adopted in 2012 to ensure that researchers' pay achieve a twofold increase over average wages in the economy by 2018 (in each of the regions across Russia).

was then demand to study remuneration problems and the scientists' productivity, including in the context of the transition to a new pay system—the effective contract.

This section presents the results of two sociological studies on human potential in Russian science, carried out in 2007 and 2013.

A survey of working conditions and scientists' values and career paths carried out in 2007 was aimed at identifying and systematizing the factors affecting the effectiveness of their activity, the choice and trajectory of their scientific careers and other parameters (Gokhberg et al. 2010). The results of this survey are significant even today thanks to the high methodological continuity in relation to previous and subsequent work carried out by the authors, as well as the relevance of the international approaches practiced in this field,[7] which ensures that the findings can easily be compared on an international level. Upon studying the results, it is important to consider the extremely favourable macroeconomic backdrop to the study—in the second half of the 2000s—and the hopes of accelerating economic growth, which, clearly, could inject some optimism into the results based on researchers' opinions and assessments.

The survey was carried out in the form of a survey among researchers representing four groups of organizations (in total, 2,902 respondents from 52 regions).

The first represented was the research institutes of the Russian Academy of Sciences (RAS) which carry out basic research for the most part.[8]

The second group of organizations surveyed was made up of state research centres (SRCs). These are major R&D institutions, usually state-owned but serving industry, and have unique research and experimental equipment and facilities and highly qualified and highly productive personnel. The Russian government assigns such institutions SRC status. At present, there are 43 of them.

The third group consisted of universities, whose share in the R&D sector in Russia is still lower than in the majority of developed countries, despite the rapid growth in public support for their scientific and innovation activity (Gokhberg et al. 2009).

Finally, the fourth group consisted of R&D units at major state-owned companies (set up by federal authorities and where the state has more than a 50 % share holding in the authorized capital).

The survey was based on a questionnaire comprising four blocks of questions:

- the state of the S&T sector and S&T policy;
- scientists' values and working conditions;

[7] Cf., for example: OECD (2005, 2010a, b, 2012), Auriol (2010), Auriol et al. (2013), Kahn and McGourty (2009), Musselin (2004, 2005), Huisman and Bartelse (2001).

[8] As a result of the reorganization of the RAS and other state academies of sciences in 2013 the majority of their subordinate research institutes were "subjugated" to an authority set up specially to administer them: the Federal Agency for Scientific Organizations (FASO).

- the trajectory of their scientific career;
- international scientific collaboration.

Below are the results of the survey of respondents' values and working conditions. To assess the findings, questions relating to the factors affecting the choice and length of their professional careers, job satisfaction, main results and the potential for labor mobility were used.

In 2013, another sociological study of human potential in the Russian scientists was carried out by the Higher School of Economics (HSE). It solved the problem of evaluating past changes and the development prospects of the situation in the context of increasing pay and productivity among researchers, as well as the motives, preferences and other factors shaping the opportunities and efficiency of work in the R&D sector and the development of the scientific labor market. In terms of its target orientation, coverage of R&D sector organizations and the structure of the questionnaire, this work largely echoed the 2007 survey with some "adjustments" to the new economic conditions and political agenda.

300 directors of R&D organizations and more than 1,200 researchers were surveyed. Relatively homogeneous groups of state-owned organizations in key segments of the civil R&D sector were studied.

The target sample included, as in 2007:

- research institutes of state academies of sciences—100 organizations, 355 researchers;
- national research universities[9] (NRUs)—20 organizations, 75 researchers;
- other universities—80 organizations, 321 researchers;
- SRCs—30 organizations, 194 researchers;
- other public R&D organizations—70 organizations, 276 researchers.

Unlike the 2007 survey, this time it was not only the directors of the organizations that were interviewed, but also six categories of researchers (department/laboratory directors, head, lead, senior researchers and junior research fellows).

The survey method comprised a survey of respondents based on the corresponding questionnaire (for directors of organizations and for researchers) containing nearly 40 questions about factors and the motivations affecting their scientific work, public policy measures and the parameters of an effective pay model.

[9] In Russia, the category of national research universities includes 29 leading universities which won in a competitive selection of development programs and received the corresponding formal status and additional budgetary funding.

11.3 Working Conditions, Value and Career Orientations of Scientists: Results from the 2007 Survey

The survey made it possible to explain the dynamics of the quantitative characteristics exhibited by Russian researchers depending on the state of the R&D sector, as well as to formulate proposals to refine the focus of public S&T policy with a view to ensuring its adequacy in the face of key human resource development problems in this area.

As an integrated assessment of the state and prospects of the R&D sector and S&T policy, and researcher work satisfaction, the distribution of their responses to questions on whether they would have chosen to work as a scientist today (i.e. at the time of the survey) and whether they would have picked it for their children were examined (Table 11.2).

The seemingly minor variation in responses to these questions depending on respondent age can be easily explained, and is worthy of further explanation. The proportion of scientists who were prepared to repeat their professional choice in 2007 among those under 40 years of age was 69 %, from 40 to 60 years 65 %, and over 60 almost 74 %. In our view, this suggests that those among the "younger" age group (under 40 years), who mostly embarked on their scientific career in a period of protracted systemic crisis in the R&D sector in the 1990s, were able to adapt to the changing conditions and carve out a niche for themselves. For those in the 40–60 years bracket, the crisis came in the most active and productive period for research activity. It was accompanied by a downturn in research fundig and allied working conditions and subsequent missed opportunities. As for the eldest group, which started to work in this position before the crisis, it would seem that they worked through psychological factors, including the commitment to research irrespective of pay, the lack of alternatives at this stage in life's journey, etc.

The relatively low desire to opt for a scientific career in 2007 conditions shown by researchers from SRCs signals the unfavourable situation in the applied R&D segment, a substantial proportion of which is carried out at such centres.

Table 11.2 Indicators of researcher job satisfaction (share of respondents for each group of organizations giving positive responses: "Unconditionally" or "More than likely", %)

Indicators	Total from the sample	SRCs	RAS research institutes	Universities	Research units of state-owned companies
Would you "repeat" your choice of profession as a scientist today? (i.e. in 2007)	68.0	62.2	72.6	69.7	66.4
Would you want your children to work in the sciences?	40.5	35.7	41.1	43.7	44.5

Source: National Research University Higher School of Economics based on survey data

Those wanting to see their children as scientists were significantly fewer in number than those that were prepared to repeat their choice of scientific career amid the new conditions (40.5 %). However, it would appear that the respondents in this group are satisfied with their scientific career and are entirely optimistic about the future prospects of the Russian S&T. A comparison of the results of the 2007 and 1996 surveys (Gokhberg and Mindeli 1996) can serve as evidence of the fact that, if the situation of scientists and in R&D in general does not improve by the mid-2000s, there is some hope of positive changes in the near future. Then, only 31 % of scientists over 50 years of age would choose a scientific career for their children. Similar trends emerged in population surveys on attitudes to science and innovation carried out in Russia since 1995. While in 2003 about one third of Russians (32 %) were prepared to support their children in choosing a scientific career, by 2009 this figure had raised to 43 % (HSE 2009).[10]

The 2007 survey made it possible to identify the main factors behind the choice of a scientific career (Table 11.3). This analysis is of clear interest today in terms of developing policy actions to address age-related or other imbalances in the structure of research personnel and increase the productivity of their work.

According to data for 2007, the reasons for choosing a scientific profession were predominantly "intangible" in nature (interesting work, self-fulfilment and prestige—55 %, 37 % and 21.5 % of all respondents, respectively).[11] To correctly interpret and use the resulting distribution when preparing and adopting appropriate decisions, certain parameters of the survey need to be taken into account. In particular, about 70 % of the respondents were over 40 years of age,[12] i.e. they chose their profession in fundamentally different socio-economic conditions (in the Soviet era). This could not affect the final distribution.

The ratio of the impact of higher education and school on the choice of a scientific profession (44.2 % and 13.5 %, respectively) in no way refutes the viability of bringing school-leavers into the S&T realm. But this suggests that efforts to popularize science and to attract youths to science should still be focused on students, which is what has been observed in Russia in recent years.

[10] In 2014, only about one quarter of Russians would welcome the choice of a scientific career by their children (according to the results of HSE's Monitoring of Innovative Behavior of the Population (http://www.hse.ru/monitoring/innpeople) for 2014 г. (http://www.hse.ru/news/science/140168288.html)). Judging by these and other indicators, recently the prestige of the scientific profession among the Russian people has fallen, and the "self-awareness and well-being" of scientists are undergoing very tangible changes requiring identification and analysis.

[11] In the 1990s, more than 65 % of respondents chose the "prospects of an interesting work" option (Gokhberg and Mindeli 1996). This comparison demonstrates some reduction in the role of intangible factors for motivating researchers.

[12] Which was in line with the age structure of researchers, recorded by official statistics. Among them, the share of this age group was 68.2 % in 2007.

Table 11.3 Main factors behind the choice of a scientific career (proportion of those selecting the corresponding response for each group of organizations, %)[a]

Factors	Total from the sample	SRCs	RAS research institutes	Universities	Research units of state-owned companies
Prospect of interesting work	54.5	58.2	56.0	54.6	36.4
Teaching in higher education institutions	44.2	31.4	45.2	58.9	41.6
Opportunity for self-fulfilment	37.4	39.7	36.4	39.1	28.8
Prestige of the scientific profession	21.5	24.6	21.6	16.0	26.2
Place of work	19.1	19.9	15.7	18.6	29.6
Teaching in schools	13.5	15.1	17.2	10.8	2.6
Opinion, experience of parents	12.8	9.7	14.9	15.4	8.4
Books, film	10.7	10.1	15.5	7.8	3.1
Career opportunities	7.0	8.2	5.2	7.2	9.1
Opportunities to work abroad	3.2	4.8	3.3	1.8	1.6
High pay expectations	0.2	0.3	0.0	0.1	0.8

Source: National Research Univesity Higher School of Economics based on survey data
[a]Question: "What affected your choice of profession as a scientist (please tick no more than three of the responses that are most important to you)?"

As for the relatively low role of "material" arguments (career, working abroad[13] and high wage), the straight-line interpretation of this fact can lead to a false and even dangerous hypothesis for the R&D sector: for instance, the inadvisability of stimulating the inflow of youths into research activities by increasing pay. However, the findings can in part be explained by the specific age structure of the sample indicated above and only point to the fact that the majority of respondents chose the profession consciously guided primarily by their inclinations, their desire for self-fulfilment and interesting work, which, however, did not guarantee their subsequent entrenchment in the sciences. Similar conclusions were drawn in the 2013 study, a description of which is also presented later in this section.

[13] Taking into account the development trends of the Russian R&D sector in the last 20 years, the "materiality" of the "working abroad" factor is entirely relative, as it actually integrates the desire for self-fulfilment, achieving successful research results, personal research conditions, being a part of the global scientific community, etc.

Finally, it is important to pay attention to the specific motivation behind choosing a scientific career in state-owned companies. Their presence in the Russian R&D sector became quite noticeable thanks to growing numbers and their "coercion" to undertake R&D and innovation, for example, by requiring the development and introduction of innovative development programs (Gershman 2013). The importance of "material" factors (careers and pay) are negligible in the case of state-owned companies too compared with intangible factors, but they do surpass the average figure for the sample as a whole. This is down to the relative "youth" of the state-owned companies themselves, which emerged only in the last decade of several rounds of privatization, fusions, mergers, and the contingent of researchers in them,[14] often made up of younger scientists who deliberately chose those companies as their place of work.

Identifying and analysing the reasons for choosing a scientific career make it possible to assess the adequacy of a number of S&T policy objectives and instruments in terms of the current state and development trends in the R&D sector and to formulate proposals to refine them with a view to raising the impact and the efficiency of policy.

The system of professional values among Russian researchers is closely linked to the reasons for career continuation and mobility in the R&D sector, as well as the importance for researchers of the opportunities offered by being a scientist. In the 2007 survey, as in 1996, the main factor constraining the outflow of researchers from R&D organizations, was "interesting, creative work". This indirectly suggests that their reliance on such work when choosing a career is largely justified (Table 11.4).

Table 11.4 Reasons for continuing a scientific career (proportion of those selecting the corresponding variant out of all respondents, %)[a]

	1996	2007
Interesting, creative work	62.0	60.9
Habit, no desire for change	19.0	10.4
Hope of improving the situation in the R&D sector	37.0	20.2
Pre-retirement (retirement) age	17.0	6.9
No desire to change area of activity	14.0	12.0
Interesting environment, surroundings	11.0	36.8
Free work regime	9.0	20.9
My "team"	6.0	8.8
Opportunity for second employment	5.0	7.3
International contacts	2.0	6.4
Level of pay	0.4	3.6

Source: National Research University Higher School of Economics based on survey data [for 1996 data see (Gokhberg and Mindeli 1996)]

[a]Question: "What holds you back in science (please tick no more than three of the responses that are most important to you)?"

[14] Out of all of the researchers at state-owned companies the proportion of those under 39 years of age was higher than average in the sample—35 % and 31 % respectively, while those over 50 years was lower than average at 41 % and 51 %.

The importance of other reasons for continuing a scientific career was incomparably lower. However, not only is the ranking of the factors identified worthy of our attention, but also their dynamics in the period 1996–2007, showing a certain stability in the socio-psychological model of scientists' behaviour, their professional preferences, values, etc. (Chepurenko and Gokhberg 2005; Plyusnin 2003; Sudas and Yurasova 2006). The sharp rise in the share of researchers reporting interesting work and surroundings as a reason for continuing their scientific career in this period (from 11 to 36.8 %) reflects an increase in the rank of affiliation to the R&D profession in the hierarchy of values. The role of the "team" (research institute, laboratory or group) in which the respondent works was generally low and fairly stable (6 % and 8.8 % respectively). The levels and dynamics of these figures demonstrates that the willingness of respondents to change their place of work in the S&T sphere is higher than those leaving it.

The fall (compared with 1996) in the proportion of those affected by "inertia" (habit, no desire for change, pre-retirement age) points to *growth in the potential for R&D sector researcher mobility*, while the interesting, creative work retained the role as the main factor curbing the outflow of researchers.

Despite the measures adopted by the government in the period 1996–2007 to support Russian S&T, the proportion of respondents continuing their scientific career in the expectation that working conditions would improve fell from 37 to 20 % (Table 11.4). Evidently, they simply did not consider the measures adopted effective, but also did not expect any significant positive changes in the future.

Thus, the importance of a number of reasons keeping scientists in R&D has changed after all. For instance, the share of those mentioning international contacts rose by more than threefold (from 2 to 6.4 %) and those mentioning salary level by nine times (!), even though it still remained low. As a result, interesting, creative work and environment continued to play the key role in holding back the outflow of researchers from the R&D sector in 2007.

The hierarchy of researchers' professional values is characterized not only by the reasons for which they are continuing their scientific career, but also by the extent to which the opportunities offered by working in the sciences are significant and the extent to which they have managed to seize these opportunities (Table 11.5).

Obviously, the status of options such as independence in managing work and the working day, the opportunity to have interests outside work, social prestige, and the feeling of belonging to a team has increased in the hierarchy of respondents' values in the period 1996–2007. Of particular note are the dynamics not only of researchers' views on the importance of the opportunities offered by R&D activity, but also of the extent to which they are realized in practice. The growth in this figure points to a slight improvement in the self-awareness and well-being of researchers and the situation in the R&D sector by 2007.

One of the key characteristics of the state of the R&D sector is its output, with various figures being used to assess this indicator. The information in Table 11.6 shows not only the range and diversity of respondents' activities and their findings, but also the need to significantly improve efficiency and introduce modern standards and practices in R&D evaluation.

Table 11.5 Importance of the opportunities offered by work in the R&D sector and their fulfilment in 1996 and 2007 (proportion of those selecting the corresponding variant out of all respondents, %)

Opportunities	Importance and fulfilment			
	Very important, fairly important		Successfully and relatively successfully fulfilled	
	1996	2007	1996	2007
Realization of professional potential	95	93.2	53	74.5
Independence in managing work, the working day	75	81.6	55	77.1
Having interests outside work	60	72.8	48	62.8
Worthy pay, material position	94	88.4	10	32.1
Making a contribution to one's scientific field	91	90.8	53	73.3
Feeling of stability, confidence in life	96	92.5	13	44.8
Realization of one's own ideas in practice	90	83.1	40	55.3
Social position, recognition	63	73.5	28	56.7
Interesting surroundings, social circle	88	73.5	65	80.2
Being part of a team, scientific school	78	82.5	57	70.5

Source: National Research University Higher School of Economics based on survey data [for 1996 data see (Gokhberg and Mindeli 1996)]

In view of modern ideas on the performance indicators and requirements for R&D output, the survey data presented is worthy of some comment.

As Table 11.6 shows, in terms of publication activity researchers predominantly focused on peer-reviewed Russian scientific journals and the internal publications of organizations[15] (60.4 % and 50.4 % of the total number surveyed, respectively). Only 17.5 % of scientists had publications in leading global journals and 12.1 % co-authored with foreign scholars. Despite the low overall figures for researchers publishing abroad, Russia's share of the global publications indexed on Web of Science reached 2.42 % in 2007,[16] with over one third of these publications (35.5 %) being co-authored with foreign colleagues (HSE 2009, p. 334, 336).

Information on the impact of applied research is not particularly optimistic, measured by the proportion of respondents with patent applications or patents granted in 2005–2007 (12.6 % of those surveyed).[17]

Although the survey was carried out in state-owned organizations, the figures reflecting respondents' involvement in projects based on the thematic plans of R&D

[15] If peer-reviewed Russian journals somehow guarantee the standard of the publications, assessing the quality of materials in organizations' internal publications is not possible. This largely devalues the importance of this publication activity indicator. The same is true of textbooks and study guides. Though 25.3 % of university researchers selected this option.

[16] In 2013, this figure fell to 1.92 % (HSE 2014b, p. 44), which mostly resulted from the rapid growth in publication activity in China and a number of other countries.

[17] The importance of this figure reflects not only patent activity itself, but also the problem of managing the rights to the results of intellectual activity obtained using public funding. Legal regulation in this domain still requires certain improvements.

Table 11.6 Results of researchers' activities (proportion of those selecting the corresponding response for each group of organizations, %)[a]

Types of results	Total from the sample	SRCs	RAS research institutes	Universities	Research units of state-owned companies
Articles in peer-reviewed domestic journals	60.4	53.1	68.2	67.4	37.3
Publications in internal publications by an organization (place of work)	50.4	46.8	40.1	64.9	57.6
Involvement in work according to an organization's thematic research plan	41.2	43.3	48.1	32.6	34.5
State science foundation grants	29.3	25.6	45.0	20.8	7.6
Work under agreements with federal agencies	26.6	33.6	29.8	17.2	18.9
Scientific monographs	21.1	15.9	25.1	24.3	14.9
Work for industrial companies	20.7	23.7	21.4	14.0	26.7
Work for foreign clients	17.5	19.9	24.1	7.9	13.5
Articles in leading scientific journals around the world	17.5	12.7	27.1	15.5	14.8
Work for regional and local authorities	16.8	16.3	20.8	12.3	16.4
Popular science publications	15.4	11.9	17.2	16.7	17.3
Patent applications and/or certificates	12.6	19.0	5.9	13.1	13.1
Co-authored publications with foreign scientists	12.1	7.8	20.5	10.1	2.7
Textbooks and study aids	11.1	5.6	7.1	25.3	3.8

Source: National Research University Higher School of Economics based on survey data
[a]Question: "The main results of your scientific activity in the last 3 years were . . . (please tick all that apply)"

institutions and contracts from federal agencies (41.2 % and 26.6 % respectively) were relatively low.[18] In the case of contracts from federal agencies, this could point to both the lack of involvement by surveyed scientific organizations in the

[18] The breakdown of work according to thematic plans and government authority contracts was affected by the fact that, for some state-owned scientific organizations (for example, for RAS research institutes) the thematic plans were approved and funded by the state without any tender procedure. On the contrary, the allocation of public R&D contracts is based on competitive procedures and involves a wider spectrum of units notwithstanding their ownership and legal forms.

tenders for these contracts (for example, due to the contracts not tying in with the organization's R&D areas) and failed tender applications.

Only one in five respondents took part in contracts from industrial companies (20.7 %) which, in essence, reflected the pressing nature of links between science and business when carrying out the survey (on the one hand, low demand from business for R&D results, and on the other, discrepancy between these results and the needs of business).

As for public research fund grants, less than one third of respondents overall indicated the existence of such cases (29.3 %). The programs of these funds are geared primarily towards supporting basic research, and so the figure reached 45 % among those from RAS research institutes. The weak appeal of such grants to other sectors can be explained by their small size.[19]

Despite the well-known conventionality of the productivity evaluations, in the 2007 survey RAS research institutes clearly stood out from the general backdrop. It was at these institutes that the highest share of researchers were seen with publications abroad, co-authored articles with foreign scientists, and grants from scientific foundations. University researchers tended to have publications in peer-reviewed Russian journals (67.4 %) and internal publications (64.9 %). The efforts undertaken by the government to force the development of university R&D activities somewhat improved the position of the sciences in the global publication arena. While in the period 2007–2013 the RAS' proportion of Russian publications in scientific journals indexed on the Web of Science varied from 51 to 57.7 %, the share of higher education institutions increased from 52.8 to 62.2 %.

With low patent activity overall by researchers (i.e. the share of respondents with patent applications and/or patents granted at the time of the survey), the situation was somewhat better at SRCs. However, the level of their involvement in work for industrial companies (23.7 % of respondents) and government agencies (33.6 %) is clearly not enough. These figures did not satisfy their mission as the leading driver of applied R&D, designed to guarantee the practical implementation of scientific results.

With respect to the age differences in performance, the fact that young researchers (under 40 years) felt behind their older colleagues in virtually all figures is particularly alarming. In light of the tangibly more strict requirements on publication activity for Russian researchers in recent years (for example, relating to the presentation of their findings in publications indexed in global scientific publication databases), the age characteristics of the R&D output figures are, in our opinion, interesting and worthy of special consideration.

[19] The expansion in grant support for research in Russia in subsequent years was not so much down to scaling up the activities of the three state scientific funds operating in 2007, but rather as a result of the creation of a new larger scientific fund in 2013, the Russian Science Foundation (RSF).

In spite of the variation in the analyzed results both within themselves and between the groups of organizations, R&D output among the 2007 survey participants was rather modest. Given the scale and intensity of the efforts undertaken in Russia to improve R&D output and integrate the results of R&D evaluation into S&T policy practice, it would be worthwhile to place an emphasis on such exercises on a permanent basis.

11.4 Professional Career Development and Opportunities to Encourage Researchers to Undertake Productive Activity: Results of the 2013 Survey

The problem of growing productivity in the R&D sector is one encountered virtually the world over. A policy of increasing the productivity of corresponding forms of activity, using modern, flexible mechanisms to organize efficient remuneration mechanisms for the key drivers of science progress—researchers, taking into account the difficult, complex, creative and intellectual nature of their work and the specific nature of their output, came to be one of the most crucial policy issues in recent years in terms of improving the situation on the academic labor market. As noted above, the relevance and validity of arranging such policy objectives has been confirmed from the data derived from the scientific personnel survey in 2007.

In international practice, the system of mechanisms to solve problems such as these is known as "performance-related pay" or "effective contract". The main aim of introducing such a scheme is to guarantee high levels of motivation and competitiveness and improve the quality and efficiency of researcher activities. It is believed that widespread use of such mechanisms will make it possible to expect relatively rapid positive shifts in the field, not only in relation to pay (achieving an effective level of pay), but also in relation to S&T development as a whole (OECD 2005; Gershman 2013; Gershman and Kuznetsova 2014).

Support for scientists in the form of encouragement to carry out productive work and the introduction of effective pay systems and mechanisms in Russia has been implemented for many years through fragmented, one-off solutions. With this, the total wage level in the R&D sector since 2010 has been roughly 20 % higher than the average for the economy as a whole. Its basic component is based largely on seniority, position and bonuses for advanced degrees.

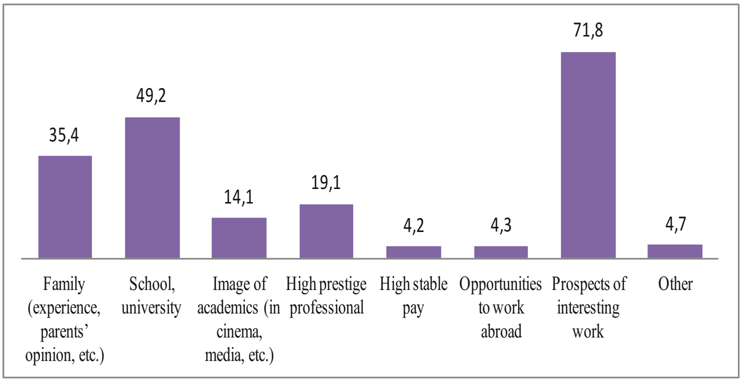
The relevant issues regarding productivity, dynamics and the economic output of R&D activities were raised by federal authorities in 2012–2013. Measures were developed to improve funding, to implement institutional reforms, and to introduce a new remuneration system for researchers. As already noted, the decision was made to raise the level of pay for researchers and to introduce a new pay system based on the "effective contract" concept, which implies regular evaluations of researchers' productivity and active use of bonus payments to reflect the volume and quality of the work carried out.

This section presents the results of a researcher survey carried out by HSE in 2013.[20]

The average age of the respondents in the survey was 45 years (slightly below the average researcher age in Russia of 48 years). The proportion of doctors and candidates of science in the sample, on the contrary, was higher than average, which is due to the specifics of the study object: public R&D institutions and their researchers.

Analysis of the motive and preferences of the researchers showed that, as before, their first preference is for research occupations linked to interesting work and that they would make the same professional choice again (Fig. 11.2).

A. Question: What, above all, influenced your choice of a profession as a scientist?



B. Question: Would you choose the scientific profession if the same question was asked of you again today?

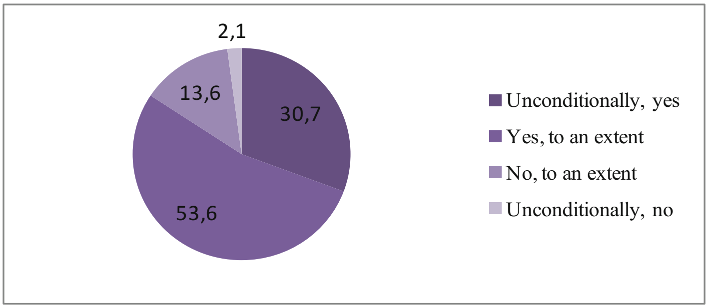


Fig. 11.2 Motives for starting a scientific career (proportion of respondents selecting the corresponding option out of those surveyed, %). *Source*: National Research University Higher School of Economics based on survey data

[20] The section mostly presents the results of the survey for the sample as a whole (without identifying institutional or role-based groups).

In making their choice, scientists understand that the sciences will never bring in (can never bring in) incomes that are comparable with other areas of activity. This, incidentally, does not mean that the material component holds no interest for them. A significant proportion of respondents (65–80 % in different categories) believe that their families have only enough money to tend to their immediate needs; roughly 18 % are relatively satisfied (they can buy everything apart from an apartment). To meet the needs of families, the individual incomes (and salaries) received in the R&D activities need to increase significantly.

Unlike previous surveys, a comparatively large number of scientists said that they would make the same professional choice again today. This trend has emerged, it would appear, amid a certain increase in pay in the R&D sector compared with average levels for the economy as a whole, as well as expectations of new incentives from the state in this field.

Being engaged in R&D, more than 90 % of respondents attached special importance to *opportunities to fulfil their professional potential* (knowledge, experience, abilities); two thirds chose the option “very important”. The spread in the choice of other opportunities is illustrated in Table 11.7.

Researchers view the opportunities offered to them by their current job very differently. Thus, only 26 % of researchers can fully realize their professional potential. This means that there is a significant discrepancy between the “ideal” and existing models of organizing R&D activities, even in the eyes of those scientists who are generally satisfied with their work and do not want to change it.

Clearly, the motivations and the value characteristics identified, on the one hand, confirmed the difficulties on the path to reforming the R&D sector and improving its performance. On the other hand, they suggest that the scientific community itself as a whole is ready for reform and understands the direction in which to proceed. Furthermore, professionals are forming an entirely modern and effective model for organizing their activity in the R&D sphere in their expectations.

Table 11.7 Importance of additional opportunities offered by scientific activity and their fulfilment in practice (proportion of respondents selecting the option “very important” out of those surveyed, %)

Opportunity:	Very important	Successfully fulfilled
Feeling confident in life (factors intersecting, but not coinciding with material wealth)	66	11
Making a contribution to a specific scientific field	54	23
Working with like-minded people	54	32
Acquiring additional knowledge, skills	53	30
Receiving good pay	51	7
Developing one’s own ideas in the interests of knowledge	47	17
Independently managing one’s work	38	21
Leading life in accordance with one’s interests outside of work	35	19
Working in a well-known, successful organization	34	23

Source: National Research University Higher School of Economics based on survey data

Intentions to change jobs are linked to material factors for roughly 55 % of those surveyed. Among other motives that are frequently mentioned are: personal circumstances (27 %), uninteresting work (19 %), lack of modern equipment (17 %), and curtailment of research in a particular field of science (16 %).

As a general rule, researchers on the whole are not eager to leave the organizations at which they work. Almost 22 % remarked that they could not conceive of a situation that would compel them to leave; 24 % of researchers intend to stay in science in any case; and 13 % would like to continue their studies abroad. Next, in descending order, are intentions to start teaching, start up a business, or work in the government. Scientists would only agree to move over to routine work with a significant (3–4 times) increase in pay. The most demanding on this point were researchers occupying senior positions.

Employment in public R&D institutions helps to develop scientists' professional careers in different directions. Thus, 60 % of respondents pointed to the possibility of furthering their qualifications or obtaining a second or additional education. For the most part, this meant taking part in educational programs to raise the levels of qualifications in Russia. Fairly often it referred to postgraduate/doctoral studies (19 %) or training and defending theses (18 %). Only a minimal number of researchers from all groups surveyed called for an important option, in terms of developing their scientific career, such as study abroad. In this respect, according to the respondents, neither additional education or further qualifications provide tangible benefits for a transition to a new job, including in a foreign company.

Each of the following three options (in order of importance) (promotion, salary increase, involvement in future projects or work on new areas) were chosen by only 20 % of respondents.

Analysis shows the similarity of the ratings given to the motives and preferences among different groups of researchers. The only exception is the researchers in the as yet small group of NRUs, which have a slightly more optimistic outlook than others. This is seemingly due to the relatively more favourable conditions surrounding their activity, supported to a large degree by the efforts of the state, as well as the expectations of possible improvements in the future.

Additional Employment and Working Hours In Russia there was once a strong opinion that secondary (additional) employment was widespread in the sciences, due to the need for extra income, highly qualified employees and free time. Empirical data only partially corroborate this hypothesis. Almost 46 % of respondents indicated that they are only engaged in their main line of work. The average duration of the working week for the majority of those surveyed was 4.9 days. 26 % of respondents carried out permanent additional work during the course of the year.

The main reasons for secondary employment are clear (Fig. 11.3). In particular, there is the need for additional income (43 % of those surveyed ticked this option), a desire to fulfil one's professional interests (32 %), and such employment serving as a means to maintain business contacts (18 %).

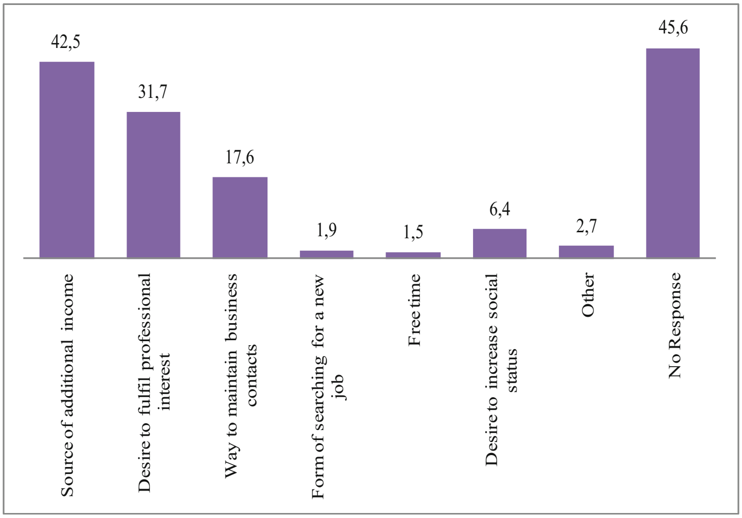


Fig. 11.3 Reasons prompting researchers to take on additional work (proportion of respondents selecting the corresponding option out of those surveyed, %). *Source*: National Research University Higher School of Economics based on survey data

In terms of types of activity, during the course of a relative (averaged) working week, research prevailed for 57 % of respondents as the *main duty at their main place of work*. If one also takes into account the time spent by them on research outside the work place, as well as the various forms of side jobs in the sciences, research activity dominates for 73 % of scientists. Among the other types of activities identified were administrative and managerial (12 %) and communication and social (4.4 %) functions. All other work (including tutoring, teaching, consulting) take up very little time on average.

Performance and Competitiveness Based on the survey results, the productivity of scientists in public R&D institutions is still not very high. Each year, the "average" scientist produces 0.9 articles indexed in the Web of Science or Scopus, 2.4 articles in leading Russian journals, receives 0.4 Russian intellectual property protection documents, and takes part in 1.3 foreign and 1.6 Russian scientific events. All other results (for example, carrying out projects won through competitive tenders or under business contracts) are far less significant. The results of our survey are broadly consistent with statistical data on the low productivity of activity in the S&T sphere in Russia (as with the data from previous surveys). However, these figures do not tie in with the appraisals of competitiveness in the sciences and development prospects. 60–70 % of respondents consider the competitiveness of R&D results in Russia to be on a global level or higher. The share of such "optimists" grows over time from the past to the future. Several scientists have viewed the situation differently, when the question was asked in a different way: what has happened in the Russian sciences in recent years. Here the group of "optimists" was far smaller, but was sufficiently representative.

Preliminary Assessments of Problems Relating to the Transition to the New Remuneration System (effective contract) The survey was conducted at the start of this process, but scientists' assessments of the likely effectiveness of the proposed measures do still present some interest. Moreover, some of these assessments were corroborated during the course of this transition. The survey allowed for certain critical aspects to be identified which deserve special attention when developing and adjusting regulatory measures in general and in the field of researcher pay in particular.

The problem of the professional community's awareness[21] of state policy measures is continually rising in Russia and is multifaceted in nature. Such assessments make it possible (albeit indirectly) to judge the quality of specific decisions and their perception by the professional community, the effectiveness of feedback channels between the latter and administrative structures, etc. Awareness is important for scientists too. It allows them to improve efficiency under certain constraints and known prospects, and, potentially, to influence policy itself. However, our survey has shown that Russian scientific personnel (especially in the public sector) are inherently inert and passive, which is evident even in relation to decisions that affect them directly.

Thus, approximately 36 % of respondents (who first learnt about it from the questionnaire) were initially unaware of the transition to performance-related pay (which aimed to increase pay and raise requirements to performance, among other things), which is strange, considering the level of appropriate decision-making, the urgency with which the authorities moved on the matter, and the media time given to the matter. Only 18 % were fully aware of the planned changes; the majority had just "heard something somewhere".

Generally, the researchers approved of the actions to *link pay to performance evaluations*. However, in their opinion, a large number of conditions and requirements needed to be fulfilled. According to respondents, it is important to take into account the fact that:

- the results of scientific work may emerge after a long time (47 % of respondents selected this option);
- the guaranteed salary of scientists needs to be increased (43 %);
- the conditions of scientific work need to be improved (42 %);
- performance cannot be the only factor taken into account when determining the level of pay (35 %).

Other circumstances (the use of international standards, involvement of the expert community, institutional reforms, etc.) seem less important to scientists.

Although the majority of respondents indicated that *the process of filling positions* in their organizations includes elements of assessing scientific results,

[21] Gokhberg et al. (2009, 2011).

they considered stricter requirements for candidates ineffective. Almost 43 % of respondents remarked that it will be a formality. Only 28 % of those surveyed considered stricter requirements would provide an incentive for more productive work.

Judging by the respondents' views, *mechanisms to determine incentive payments* and the amount of such payments differ considerably. Only 11 % of respondents said that their organizations do not use such payments. Approximately one third of those surveyed noted that they received incentive payments on a regular basis (at the end of the year or as a permanent part of their pay each month). There are also models where the incentive payments are awarded regularly, but in varying amounts or, on the contrary, irregularly. Roughly 18 % of organizations practice a model of awarding pay for individual performance (alongside other incentive payments).

46 % of respondents were satisfied with the current incentive pay award mechanism; 26 % considered them to be appreciable; and 28 % thought that the terms were clear and transparent. Almost 20 % considered the incentive pay mechanism to be opaque and 6 % believed them to generate tension and conflict in the team.

The conditions/grounds for awarding incentive payments were extremely diverse. In roughly equal proportions (18–25 %) the respondents identified options such as international publications and scientific reports; managing research projects and temporary groups; involvement in research grants and projects for external clients; administrative and organizational work; and personal contributions to the scientific reputation of an organization. Virtually nobody mentioned translation and editorial activity; improving their level of education; participating in educational activities and international collaboration; membership of collective and public bodies, etc.

The *effects of introducing additional incentive payments* (the impact on employees and productivity) were rather ambiguous among the respondents. Less than half of those surveyed (44 %) considered that they were already working effectively, and emphasis should be placed on increasing the guaranteed salary. According to 57 % of researchers, raising the basic salary is the priority factor (answering "unconditionally, yes") in terms of raising scientific productivity overall. Alongside the option "to some extent", the proportion of adherents to a pay model with a high share of basic salary exceeded 90 %.

At the same time, scientists do not consider this factor to be the only one. Performance in the sciences is determined by factors such as:

- the purchase of modern equipment; individual efforts by the worker; increasing the availability of grants from research foundations (more than 50 % of respondents);
- expanding access to additional public and private sources of funding; reducing the administrative burden (40–50 %);
- developing international collaboration (30–40 %).

Leverage such as changing the qualification requirements, adjusting the management structure, improving the culture of team collaboration, and getting rid of “ballast” is not viewed as being significant in terms of increasing R&D productivity.

Of particular importance in discussions on assessing individual performance is the *problem of taking into account highly rated international publications*. In principle, respondents agreed that such an approach is common practice. However, more than half of them were of the view that performance should be interpreted more broadly to include other indicators linked to scientific, educational, administrative and other work loads.

Of course, the researchers at NRUs were the only ones who accepted the focus on international publications, as their growing presence in the global scientific arena is one of the criteria for maintaining this status, and international publication activity indicators are already used to appraise researchers at these universities for their suitability for the scientific role in question.

Scientists note that during the course of their work there are a lot of objective factors that hold back growth in their publication activity on an international level: high workload (33 % of respondents), lack of necessary materials or special data (20 %), poor financial incentives (21 %), and the specific nature of the scientific field (11 %). Subjective reasons include the lack of experience and skills in creating and promoting publications (22 %), the lack of necessary contacts (13 %), and insufficient knowledge of foreign languages (27 %).

Nearly one-quarter of respondents (23 %) are convinced that publication activity figures do not give an objective assessment of the quality of scientific work.

The results obtained are another clear demonstration of the fact that the transition to the effective contract cannot be reduced simply to an increase in pay (including the guaranteed component). Even the researchers, who in theory would have to accept the need for such growth without any reservations, identify a number of important conditions and circumstances without which the investment of public financial resources in raising pay would be largely meaningless.

The results presented in this study of the human potential of the Russian R&D sector are based on empirical data covering the period up to 2013. In 2014, new and, unfortunately, not especially favorable macroeconomic (domestic and foreign) and geopolitical factors started to emerge for the R&D sphere. It is therefore important not only to continue, but also to expand the range of studies on the medium-term prospects of developing human potential in S&T, making it possible to identify and analyze the changes occurring in the self-awareness and well-being of researchers, their performance motivations, the system of professional values and preferences, and reactions to S&T policy measures.

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References

Auriol L (2010) Careers of doctorate holders: employment and mobility patterns. OECD Science, Technology and Industry working papers 2010/04. Paris: OECD Publishing. doi: 10.1787/5kmh8phxvvf5-en

Auriol L, Misu M, Freeman R (2013) Doctorate holders: labour market and mobility indicators. Foresight-Russia 7(4):16–42

Chepurenko A, Gokhberg L (eds) (2005) The reproduction of the scientific elite in Russia: the role of foreign scientific funds (as exemplified by the Humboldt Foundation). Russian Independent Institute for Social and National Problems, Moscow [in Russian]

Dezhina I (2014) Intersectoral mobility of the scientific staff—global trends and Russian peculiarities. Public Adm Issues 3:30–48

Gershman M (2013) Innovation development programmes for the state-owned companies: first results. Foresight-Russia 7(1):28–43

Gershman M, Kuznetsova T (2014) Performance-related pay in the Russian R&D sector. Foresight-Russia 8(3):58–69

Gokhberg L (1990) The scientific potential of the USSR. VINITI, Moscow

Gokhberg L (2003) Statistics of science. TEIS, Moscow

Gokhberg L, Mindeli L (eds) (1996) Russian academic science in estimates of scientists. Centre for Science Research and Statistics, Moscow

Gokhberg L, Nekipelova E (2002) International migration of scientists and engineers in Russia. In: OECD (ed) International mobility of the highly skilled. OECD Publishing, Paris

Gokhberg L, Kuznetsova T, Zaichenko S (2009) Towards a new role of universities in Russia: prospects and limitations. Sci Public Policy 36(2):121–126

Gokhberg L, Kitova G, Kuznetsova T, Shuvalova O (2010) Russian scientists: outlines to a sociological portrait. HSE, Moscow

Gokhberg L, Kitova G, Kuznetsova T, Zaichenko S (2011) Science policy: a global context and Russian practice. HSE, Moscow

HSE (2006) Science indicators: 2006. Data book. HSE, Moscow [in Russian]

HSE (2009) Science indicators: 2009. Data book. HSE, Moscow [in Russian]

HSE (2014a) Science indicators: 2014. Data book. HSE, Moscow [in Russian]

HSE (2014b) Science and technology. Innovation. Information society: 2014. Pocket data book. HSE, Moscow

Huisman J, Bartelse J (eds) (2001) Academic careers: a comparative perspective. Report prepared for the Dutch Advisory Council for Science and Technology Policy on academic careers. Enschede. Available at: http://doc.utwente.nl/7812/1/academic.pdf. Accessed 18 Jul 2014

Kahn C, McGourty S (2009) Performance management at R&D organizations. Practices and metrics from case examples. The MITRE Corporation, Bedford, MA

Kitova G, Kuznetsova T (1997) Mobility of Russian R&D personnel in the 1990s: magnitude and consequences. Sci Technol Soc 2:407–433

Kitova G, Kuznetsova T, Kuznetsov B (1995) Mobility of R&D personnel in Russia: scale, pattern, and implications. Stud Russ Econ Dev 6(4):306–313 and 6(5):408–415

Kuznetsova T (2013) Russia. In: Scerri V, Lastres HM (eds) BRICS. National system of innovation. The role of the State. Routledge, London, pp 80–137

Musselin C (2004) Towards a European academic labour market? Some lessons drawn from empirical studies on academic mobility. High Educ 48:55–78

Musselin C (2005) European academic labor markets in transition. High Educ 49:135–154

OECD (2005) Paying for performance: policies for government employees. Policy Brief. OECD Publishing, Paris

OECD (2010a) Performance-based funding for public research in tertiary education institutions: workshop proceedings. OECD Publishing, Paris

OECD (2010b) Skills for innovation and research, OECD innovation strategy. OECD Publishing, Paris

OECD (2012) Transferable skills training for researchers: supporting career development and research. OECD Publishing, Paris
Plyusnin S (2003) Guild psychology of a scientist, or on loyalty to the chosen specialism. Sci Stud 2:101–110 [in Russian]
Sudas L, Yurasova M (2006) Has the “Idiosyncrasy Syndrome” of Russian sciences been overcome? Russ Acad Sci Bull 76(6):214–221 [in Russian]
Zaionchkovskaya Z, Azrael G (eds) (1994) The migration of specialists from Russia: causes, effects, assessments. Centre for Science Research and Statistics, Moscow [in Russian]
Zaionchkovskaya Z (2004) Labour emigration among Russian scientists. Studies on Russian Economic Development 4: 98–108 [in Russian]

A National Approach to Realising the Potential of Researchers: The Case of the UK

12

Ellen Pearce and Janet Metcalfe

12.1 Background and Policy Context

The UK has been engaged in a deep phase of debate and policy development relating to doctoral careers during the last 15 years. Much of this was a result of an influential review undertaken by Professor Sir Gareth Roberts in 2002 which looked at the supply of science, engineering, technology and maths people and concluded that we were not preparing early career researchers adequately for their future careers (Roberts 2002). As a result of the review, approximately £120 m of government funding was invested in improving skills, employability and career development support for doctoral researchers and research staff in UK higher education institutions (HEIs).

Since then, a raft of related policy (Leitch 2006; Warry 2006; QAA 2012; RCUK Statements of Expectations 2013) has been put in place to ensure that doctoral researchers have an opportunity during their research to reflect on their personal career aspirations and the potential transferability of the research experience. With increasing numbers of doctoral researchers in UK higher education (HE) and the wide range of careers that doctoral holders undertake, it has been important to reflect on the doctoral experience as preparation for those diverse careers.

12.2 Who Are Doctoral Researchers in the UK?

To consider the career interests and outcomes of doctoral holders, it is useful to firstly reflect on what we know about doctoral candidates studying in UK HEIs.

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In total, according to the 2012/2013 Higher Education Statistics Agency (HESA) dataset, there are nearly 108,000 doctoral researchers registered in UK HEIs, an increase of approximately 20 % in the last 10 years. Of these, approximately 64,000 (59 %) are UK domiciled and 45,000 (41 %) from overseas. There are about 35,000 new doctoral starters each year in the UK as a whole.

The latest information, published in September 2014 by the Higher Education Funding Council for England, identifies that two thirds of doctoral researchers have a prior postgraduate qualification when they start their research degree programs in UK universities, usually at Masters, level. This is a significant increase compared to 2002/2003 when only one third of doctoral starters had such a prior qualification (Hill et al. 2014). Increasingly, there is a need for doctoral researchers to be able to evidence prior research experience as part of the selection process for being accepted onto a postgraduate research degree program in UK universities (Mellors-Bourne et al. 2014).

However, this picture varies significantly by discipline. In the sciences, particularly physical sciences, engineering and mathematical sciences, doctoral researchers are more likely to have transitioned directly from an undergraduate program. For education, law and other creative industry disciplines the trend is reversed and the majority of those undertaking doctoral research will have a prior postgraduate qualification (Hill et al. 2014).

There are a range of doctoral qualifications available in UK HEIs that reflect the needs of doctoral researchers and the traditions of disciplines and related professions. In essence, there are two main types of doctoral degrees. A doctor of philosophy is the most common model, and is usually based on a research project which lasts 3 or 4 years. The qualification that is awarded is a PhD or DPhil. Over the last few years, there has been a strong emphasis on embedding the explicit acquisition of skills and capabilities and the transferability of these to future employment settings. It is assessed through a thesis or portfolio based on the extended research conducted. In addition, increasing numbers of PhDs are carried out through structured doctoral training programs and/or involve collaboration with business or other organizations. The other model is gaining a professional or practice-based doctorate, where the qualification awarded is an EdD, DBA, DClinPsy, DSocSci, DProf or similar. This is often the best choice for mid-career professionals as these programs are normally located in the work environment of the doctoral candidate's profession or related to their area of practice. For example, they are often undertaken by artists, musicians, educators, and health professionals. Sometimes linked to a licence to practice, they are often designed to meet the needs of that profession. Such doctoral programs normally include a structured period of initial research training and the assessed outputs may include practice-based materials, as well as a written commentary or thesis.

All UK doctorates require the main focus of the candidate's work to be their contribution to knowledge in their discipline or field, through original research, or the original application of existing knowledge or understanding. In professional and practice-based doctorates, the research may be

(continued)

undertaken in the workplace and so have a direct effect on organisational policy and change, as well as improving personal practice (Quality Assurance Agency 2011).

12.3 What Do Researchers Want to Do?

The career intentions of doctoral candidates are varied and usually become clearer and better articulated during their doctoral experience. For example, in a survey of over 4,000 current doctoral candidates in 130 UK universities and research institutes, fewer than one in six were clear about their career ideas at the start of their undergraduate degree (Mellors-Bourne et al. 2012). This implies that an interest in research was sparked during their university experience, which subsequently led to the enrolment on a postgraduate research program. In fact, the majority reported that they chose to undertake doctoral research for intellectual curiosity and interest (Mellors-Bourne et al. 2012), a finding supported by another UK-wide survey of 48,000 postgraduate researchers (Bennett and Turner 2013) where the two main motivations for study were interest in the subject and to improve prospects for an academic or research career.

By the final year of the doctorate, researchers generally have much clearer career intentions (Mellors-Bourne et al. 2012). 84 % reported either having a clear career in mind or considering from a range of options. How these intentions are met is covered later in the chapter.

12.4 Doctoral Experiences

The experiences of doctoral researchers in the UK are well documented through the UK-wide Postgraduate Research Experience Survey (Bennett and Turner 2013) and the Vitae 'What do researchers do?' series. In particular, these sources examine how doctoral experiences contribute to future careers, and the underpinning frameworks for enhancing employability and exploring the impact of training and development on researcher careers.

12.4.1 Defining the Capabilities and Expertise of Researchers

First, we look at the underlying frameworks. In 2002, the Research Councils all signed up to a statement, then called the Joint Skills Statement, which was developed in conjunction with the UK GRAD Program (the forerunner of Vitae which operated between 2002 and 2008). This was a collective agreement about the range of skills that a doctoral graduate was expected to be able to demonstrate by the time they had completed their research degree. The Research Councils acknowledged their role in setting standards and identifying best practice and the statement was subsequently referenced in funding calls and provided the framework at UK level which underpinned the early work under the 'Roberts' agenda. It was also referenced by the Quality Assurance Agency Code of Practice for the assurance of academic quality and standards in HE, Section 1: Postgraduate research programs. This guidance set out their quality principles for doctoral programs against which UK HEIs are audited which has subsequently been updated into the UK Quality Code Chapter B11: Research degrees.

The skills were grouped into seven sections, which covered research skills and techniques, the research environment, research management, personal effectiveness, communication skills, networking and team working, and career management. The statement explicitly stated that these skills may already be evident at the time of starting a research program and could be developed through explicit teaching or informal opportunities as part of the doctoral experience. These skills were considered a core part of the doctoral process and as such were intended to complement and underpin the individuals' development as a researcher where the expectation is that a doctoral degree makes a substantive contribution of original new knowledge.

For many years, the Joint Skills Statement provided an invaluable reference point as HEIs significantly increased their training and development support for doctoral researchers. It enabled the policy-making, academic, training and researcher communities to share a common language and set of definitions at a time when much infrastructure was being developed to better prepare researchers for future careers and when much public investment was being made.

However, by 2006 a new set of policy reviews and related reports emerged which built on Professor Sir Gareth Roberts' earlier insights and recommendations. The Leitch Review explored the UK's development of world-class skills as a means to future prosperity. While the review primarily focused on school level, first degree and apprenticeship qualifications, there were some clear statements about the important role of higher level qualifications, including doctoral degrees, in achieving higher productivity across the UK. It was these skills that were highlighted as being particularly significant in the drive for greater innovation, entrepreneurship, and links between industry, HE and leadership (Leitch 2006).

The Warry report, also published in 2006, focused on improving the economic impact of the Research Councils against a public policy dialogue on the need for government funded research to be accounted for in terms of the social, cultural and economic returns on investment. The role of early career researchers in undertaking enterprise activities was highlighted, and a recommendation made that enterprise training should also be a key part of the doctoral experience (Warry 2006).

Against this backdrop, there was also an emerging view amongst Vitae's growing community of staff engaged in the professional development of researchers that the Joint Skills Statement could usefully be updated to more fully represent the full range of researcher skills. At the same time, there was an increasing focus on research staff in HE, particularly postdoctoral researchers and those employed to undertake research, and how we might better support their career development. The Vitae team began an ambitious project to redefine the framework for researcher knowledge, capabilities and expertise in a way which would reflect the full spectrum of the researcher's career and addressed the following recommendation from a project to define a Research Careers Mapping Tool: 'A fundamental issue that has repeatedly emerged throughout this project is the lack of clarity about what constitutes a research job/career, and about the defining characteristics of a 'researcher'. There is no overarching 'framework' on which to contextualise the mapping of research careers' (CRAC 2006).

In March 2009, Vitae set out to fund and develop a new framework of researchers' capabilities. The culmination of this project is the Vitae Researcher Development Framework (RDF) (Vitae 2010a) and the associated policy statement, which was launched in its final version in September 2010 (Vitae 2010b). The Vitae RDF sets out the knowledge, behaviours and attitudes of researchers in four sections: knowledge and intellectual abilities; personal effectiveness; research governance and organization; and engagement, influence and impact. The Researcher Development Statement is a strategic policy reference document for policy makers and research organizations, and is endorsed by over 30 UK organizations including the UK Research Councils, Universities UK and the Quality Assurance Agency. The Researcher Development Statement sets out what researchers require in order to be effective in undertaking their research and in contributing to society more widely and in their future careers (Fig. 12.1).

The RDF was developed through empirical research using a phenomenographic approach and through a process of reaching community consensus. It was proposed that if a broad range of successful researchers' views were captured, it would be possible to identify the main capabilities and expertise that would apply to any researcher. To do this, over 100 in-depth interviews were carried out with a broad range of researchers from a variety of disciplines and at different career stages. These were supplemented with two focus groups, each including around 25 researchers. Once an outline framework had been created, an extensive consultation across the research sector took place, including feedback and validation from non-academic employers, research funders and other stakeholders, and subsequent iterations were made (Reeves et al. 2012).

The Vitae Researcher Development Statement and Framework have since been strongly integrated into the research landscape in the UK and increasingly further afield, for example the USA, Australia, Japan, Europe and Africa. They provide a framework which has strategic and operational relevance for organizations, and is useful for individual researchers when considering their careers. At an organizational level, the Vitae RDF can be used to underpin strategies for attracting, developing and supporting the careers of researchers, as well as providing an operational framework against which to map courses, resources and informal support. For principal investigators, supervisors, early career researchers' line managers, and the researchers themselves, the RDF provides a robust framework to guide conversations about professional development, skills acquisition, priorities and future careers. It enables self-assessment, benchmarking, team discussions and action planning based around the evidence-based definitions of what successful researchers actually do.

Vitae has also developed and published a series of lenses on the R&D Framework which focus on knowledge, behaviours and attributes that

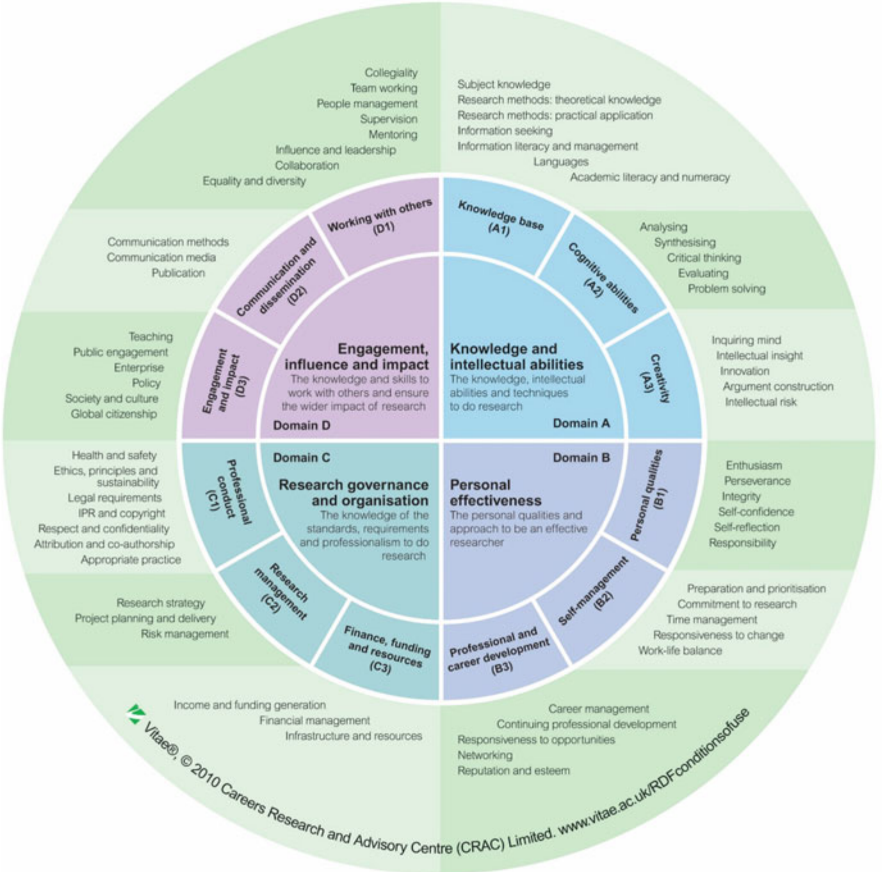

Fig. 12.1 Vitae Researcher Development Framework

are developed or used in specific aspects of being a researcher. Looking at professional development through such a lens can help researchers strengthen their academic profile or prepare for transition into a new area of work. The series of lenses include getting started in research, leadership, teaching, public engagement, enterprise as well as employability and they highlight a sub-set of the most relevant capabilities and expertise. The employability lens highlights the key competencies employers look for when recruiting researchers and focuses on those that can be applied or acquired working outside HE research, as identified by a wide range of employers through research and consultation (Vitae 2012–2014).

What has become evident recently is that there is a strong need for well evidenced definitions of researchers' capabilities which have international comparability and relevance. Recognising this need, the European Science Foundation commissioned a study to better define researchers' professional profiles and to develop guidance for the continuous professional development of researchers.

The working group identified the need for a common and structured approach towards researchers' skills development. The Researcher Development Framework (RDF), as developed by Vitae (UK), offered a promising basis for achieving this goal (Metcalfe 2012). Using the same methodological approach as in the UK trials, the RDF's suitability and relevance was tested with researchers in six European countries (Estonia, France, Germany, Italy, Luxembourg, and Norway) to include a range of research, and cultural and social and economic contexts. The final report highlights encouraging results 'in progressing towards a shared understanding of the skills and attributes that characterise modern researchers' underpinned by the RDF (Metcalfe 2012) that has been more recently supported by a European Commission working group under the remit of the Steering Group for Human Resources (HR) and Mobility to explore the Professional Development of Researchers. The Working Group report recommends that 'a framework for the professional development of researchers should be made available by the European Commission' and that 'the adoption of a professional development framework should be part of a well-functioning HR process and it would be expected to feature in an institution's plans for gaining and retaining the HR Excellence in Research Award' (SGHRM 2014).

Four years on from the launch of the Vitae R&D Framework, we see it widely used across the world, including in Australia, Japan, the US, Europe and many countries in Africa. There is also a set of emerging evaluative research papers on the use of the RDF (Bray and Boon 2011; Willey and Spencer 2014) and project-based evaluations (Reynolds et al. 2013; Pearce 2014).

During the last decade, the significant focus on explicitly articulating researchers' competencies has been critical in shaping the way that doctoral programs prepare doctoral researchers for future careers.

12.4.2 The Growth and Role of Dedicated Training and Employability for Doctoral Researchers

The report of Sir Roberts' Review, entitled 'SET for success', in 2002 (Roberts 2002) was significant not only for its recommendations but also for the fact that funding was subsequently allocated for an associated implementation program. In the area of researcher careers, the most significant finding was that the UK's doctoral researchers were not being prepared adequately for careers inside or outside academia. As a result, the report recommended that all doctoral researchers should undertake 2 weeks a year of generic transferable skills training. This recommendation was mirrored for postdoctoral researchers and early career research staff, but with a focus on career development rather than transferable skills. The UK Treasury subsequently provided funding which was allocated via the UK Research Councils for all the early career researchers who were Research Council-funded, in total around £120 M. As a result, between 2003 and 2011 universities received a ring-fenced funding allocation of approximately £800 per research-council funded researcher per year, specifically for skills and career support. For research intensive universities, this amounted to an income stream of up to £1 M per year; many HEIs, however, received little direct funding from this allocation.

Alongside this significant development, the UK Research Councils also contracted CRAC (the not-for-profit careers organization, the Careers Research and Advisory Centre, which now runs Vitae) to set up an ambitious new organization called the UK GRAD Program in 2002. The aims were to transform the experience of doctoral programs in the UK and broaden the focus from the output (a thesis) to creating a trained and highly employable researcher.

The UK GRAD Program played a key role from the start in supporting the strategic and operational implementation of the Roberts' review recommendations. For example, 'The funding mechanism was strongly influenced by the outcomes of the UK GRAD Policy Forum arranged by RCUK in January 2004. This was attended by senior representatives of over 30 research organizations who discussed issues surrounding the implementation of the 'Roberts' Skills Recommendations' for additional training of PhD students and research staff. At this Forum it was recognised that implementing the 'Roberts' Skills Recommendations' required significant resources and a radically different approach to training. It was stated at this time, and it is still the case, that the long-term aim was to see generic skills development embedded into research degree programs for PhD students and in normal staff development practices for research staff (Hodge 2010).

Over the following 8 years of Roberts' funding, there was a significant expansion of professional development provision by HEIs to better articulate, develop, and nurture the full range of competencies needed to be a successful researcher in future careers. Mandatory annual reporting by universities to the Research Councils also meant that monitoring progress and developments was a key part of the implementation and these were usually discussed by the HE sector and research funders at an annual UK GRAD Program Policy Forum.

Following the annual monitoring and significant funding for several years, the UK Research Councils commissioned an independent panel to undertake a review of progress in implementing Professor Sir Gareth Roberts's recommendations in 2010. The panel in broad terms concluded that they 'are pleased with the progress made and the foundations that are now in place for the development of the generic skills of researchers and the attention now paid to the development of their careers whether in academia or elsewhere' (Hodge 2010). Importantly, they concluded that 'Sir Gareth's views on the need for such skills and career development remain vitally important for the UK, perhaps even more so in 2010 (Hodge 2010).

A further report commissioned by Research Councils UK in 2010 as an input to the independent review analysed in detail the annual reporting from the research organizations in receipt of Roberts' funding (Haynes 2010). The research reviewed the 2004 and 2009 reporting from 95 organizations and concluded that for doctoral researchers important progress had been made. Specifically, in 2004 around one in ten [organizations] described extensive, structured provision for transferable skills training that presaged the Roberts' recommendations; over four-fifths evidenced varying degrees of transferable skills provision, available to certain groups; fewer than 10 % lacked detail on, or reported no prior provision of transferable skills.

However, by 2009 the picture looked very different with: ‘extensive, structured provision . . . indicated by three-quarters of ROs (research organizations)’ while almost all of the remaining quarter of institutions that the 2010 study looked at demonstrated partial provision of such skills. Perhaps most importantly, there was now a ‘widespread belief that institutions recognised the importance of researcher development in contributing to overall strategy’ (Haynes 2010).

Of course, many new structures also emerged within institutions during this time as they sought to balance central infrastructure and delivery of training with local departmental or faculty level provision. One significant change has been the growth in doctoral or graduate schools within UK universities.

So, 12 years on from the launch of the Roberts’ report, we can evidence a well-developed and pervasive set of careers courses, resources and interventions available to doctoral researchers in UK higher education.

12.4.3 Understanding the Careers of UK Doctoral Holders

With the increasing focus on—and investment in—the careers of researchers, understanding the careers and employment destinations of UK doctoral holders has been a critical part of the UK agenda. As well as the data collected at the UK level (see Sect. 12.5.1), Vitae has undertaken a series of research studies to explore more fully the experiences of researchers in the UK (Haynes et al. 2009; Hunt et al. 2010; Hodges et al. 2011; Mellors-Bourne et al. 2013; Hooley and Videler 2009; Bentley and Hooley 2010).

Most notably, we have clear data on the flows of doctoral graduates into employment immediately on completion of their doctorate. Of UK-domiciled doctoral graduates awarded their degrees between 2003 and 2007, 49 % of survey respondents (which represented a 65–70 % response rate) were employed in the education sector. 16.7 % were employed in health and social work, and 14 % in manufacturing (Fig. 12.2).

Fig. 12.2 Employment sectors entered by UK-domiciled doctoral graduates, as a percentage

Further analysis published in 2010 (Hunt et al. 2010) identified a set of six unique dominant employment clusters which are typical for doctoral graduates (Fig. 12.3). These include HE research occupations (19.2 %), teaching and lecturing in HE (21.6 %) and research in non-higher education sectors (13.1 %). Compared to masters and first degree graduates from UK institutions, this profile of employment is markedly different.

Based on a follow-up survey 3½ years after graduation, further analysis has been undertaken (Hunt et al. 2010) of UK domiciled doctoral graduates. There are some marked disciplinary differences that are noteworthy and the diversity of career paths is a key feature of this cohort (Table 12.1). For example, while education

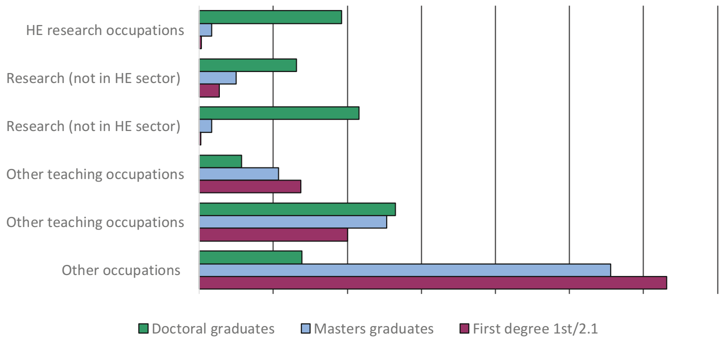

Fig. 12.3 Comparison of occupational clusters for doctoral, masters and first degree (1st/2.1) graduates in UK employment (November 2008)

Table 12.1 Employment sector of UK doctoral graduate respondents in UK employment by discipline (November 2008)

Employment sector	All	Arts and humanities	Biological sciences	Biomedical sciences	Physical sciences and engineering	Social sciences
HE	44.2%	67.0%	37.2%	40.0%	35.8%	62.1%
Education (other)	5.8%	11.8%	7.8%	2.7%	4.6%	4.2%
Finance, business and IT	10.9%	3.2%	5.0%	2.9%	24.0%	9.6%
Health and social work	13.0%	0.0%	12.4%	35.8%	1.7%	4.1%
Manufacturing	8.5%	1.3%	12.2%	5.6%	15.3%	0.6%
Research & development	9.0%	3.0%	14.8%	7.5%	10.8%	8.2%
Public administration	4.9%	3.4%	5.5%	5.2%	3.5%	6.8%
Other sectors	3.7%	10.3%	5.0%	0.4%	4.2%	4.3%
(N)	1615	180	220	450	550	180
HE in 6 months, for comparison	46.6%	62.6%	42.5%	40.6%	41.3%	65.2%

remains the most common sector for employment for all disciplines (44.2 %), those from the arts and humanities (67 %) and social science (62.1 %) disciplines were the most likely to be working in HE, with those from a physical sciences and engineering background least likely (35.8 %). Conversely, physical sciences and engineering doctoral graduates were most likely to be working in IT, business and finance occupations (24 %), with biomedical science doctoral graduates least likely (2.9 %).

From the *What do researchers do?* research series published by Vitae, the diversity of both individual aspirations, experiences and subsequent careers is clear. The number of doctoral graduates that gain their research degree each year is still relatively small. In the academic year 2012–2013, 25,880 people qualified with a higher degree by research (HESA 2014).

It is also important to consider the individualistic nature of careers and career decisions, particularly within a relatively small cohort. In order to do this, further research gathered and analysed the career narratives of doctoral graduates (Bentley and Hooley 2010; Hooley and Videler 2009 and individual stories published online; https://www.vitae.ac.uk/researcher-careers/researcher-career-stories).

The fact that the storytellers' careers are rarely straightforward journeys is attributable to a wide range of factors. For many, family or caring responsibilities have driven career decisions. For some, a desire for a better or different work-life balance has motivated decisions to switch jobs or sectors or to investigate self-employment or part-time working. 'For others the ebb and flow of funding, opportunities or job stability has encouraged a rethink' (Hooley and Videler 2009, p. 5).

What emerges is that the doctoral experience plays a major role in shaping career decisions and trajectories, and that: 'overall a strong picture emerges from these stories suggesting researchers prize their doctoral experience. The doctorate is seen as an important moment in their professional development, one where they developed skills and personal qualities and made contacts that would provide capital throughout their career' (Hooley and Videler 2009).

However, more recent research currently being undertaken by Vitae explores in more detail how doctoral graduates who have worked in HE have made the transition to other employment settings (Vitae 2014: https://www.vitae.ac.uk/news/what-do-research-staff-do-next). Initial findings published in September 2014 indicate that respondents were supported in making transitions to other sectors by their personal support networks, and by the knowledge that their research and general competencies were highly transferable.

The skills that doctoral researchers develop during their research program has been the focus of much scrutiny and is at the heart of the 'Roberts' agenda. Based on the latest data from 2013, it is encouraging that four-fifths of doctoral researchers reported they had taken ownership of their own professional development during their research program (Bennett and Turner 2013).

12.5 Approaches to Evaluation and Career Tracking

With the increase in activities to support researcher careers has come a growing need to report on, understand and evaluate the impact of such interventions. This has been undertaken in two broad areas. The first is to understand more clearly the careers pathways and outcomes of doctoral graduates. The second is to explore the role that researcher development activities themselves have played in securing outcomes for individuals, organizations and the economy.

12.5.1 Destinations of Leavers from Higher Education

The primary source of data on the careers of doctoral graduates from UK HEIs is through the Destinations of Leavers from Higher Education (DLHE) designed and managed by the HESA. This consists of two surveys:

- an annual census survey of all UK and European Union (EU) graduates from all undergraduate and postgraduate courses approximately 6 months after graduation (DLHE)—the 'Early Survey';
- a 3-year follow-up survey of the DLHE respondents (L DLHE), currently undertaken every 2 years—'Longitudinal' survey.

HESA has had formal agreements with the Government since 1993 to provide data and is funded through subscriptions from all universities and HE colleges in the UK.

Institutions are required by the government to conduct the DLHE survey and supply the data to HESA in a prescribed format. The DLHE is designed and strictly controlled by HESA, which requires institutions to achieve an 80 % response rate from their UK full-time undergraduates. Institutions collect the DLHE data using an online questionnaire initially, followed by a postal survey and subsequent telephone interviews to ensure a good response rate. Respondents are asked about their employment circumstances on the census date and their experiences of their degree program. Individual responses can be linked back to the HESA Student Record, thereby providing a wide range of information on the characteristics of respondents such as sex, subject of study, and qualification. Institutions code the employment data using the Standard Industrial Classification (SIC) 2007 and Standard Occupational Classification (SOC) 2010, published by the Office for National Statistics (www.statistics.gov.uk).

UK and EU doctoral graduates are included in the DLHE census, but there is no minimum response rate requirement imposed on institutions. Nevertheless, the response rate to DLHE is consistently between 65 % and 70 % for full-time and part-time doctoral graduates. Although not yet required by HESA, many institutions include international graduates in their DLHE data collection.

The Destinations of Leavers from Higher Education Longitudinal Survey (L DLHE) was first piloted with the 2002/2003 cohort of graduate leavers and collects information on the activities of UK and EU domiciled leavers approximately 3½ years after leaving higher education. Since then, it has been conducted bi-annually by IFF Research on behalf of HESA.

The Longitudinal Survey is based on following up a selected sample of the students who responded to the corresponding DLHE Early Survey approximately 3½ years after leaving higher education. As the number of doctoral graduates is relatively small compared to undergraduate leavers, all doctoral graduate respondents to DLHE are included in the L DLHE. The doctoral graduate response rate to the L DLHE averages 45 %. Responses can be linked to the HESA Student Record and DLHE data, allowing analysis of activities by attributes such as sex, subject of study, and qualification obtained and activity at the early survey stage.

The longitudinal data provide a rich insight into the employment and study patterns of leavers 3½ years into their careers and leavers' opinions about satisfaction with their careers to date. The L DLHE includes additional specific questions for doctoral graduates, which explore the value of the doctoral degree to employers, the use of the knowledge, skills and experiences of doctoral graduates in their employment, and their views on the benefit and wider impact of doctoral study to employers, themselves and society.

HESA publishes a summary of the UK DLHE and L DLHE results and also makes the full data sets available to researchers. Institutions use their data to advise current students and recent graduates about the opportunities that might be available to them and as part of their Key Information Sets (KIS, see http://unistats.direct.gov.uk/find-out-more/key-information-set). KIS provide prospective students with useful information to help them make choices about which course to study. All published data are anonymised and all data are treated in accordance with the Data Protection Act 1998.

12.5.2 Vitae Methodologies

Vitae uses the HESA destination data to explore the early careers of doctoral graduates from UK HEIs through its 'What do researchers do?' series of publications. This is supplemented by additional survey data and qualitative research to explore in more depth individual experiences.

'What do researchers do? First destinations of doctoral graduates by subject' (Haynes et al. 2009) combined 5 years of DLHE data to create a sufficient dataset to do a more nuanced analysis of doctoral graduate destinations and occupations by subject.

'What do researchers do? Doctoral destinations and impact three years on' (Vitae 2010c) presented a new classification for doctoral occupations based on the percentage and numbers of people with doctoral qualifications within the UK population employed in different employment sectors and occupations according to the UK Labour Force Survey (LFS). The methodology created six occupational 'clusters', of which five are classified as typical doctoral occupations. The six clusters are: HE research occupations, Research (non-HE sector), Teaching and lecturing in HE, Other teaching occupations, Other common doctoral occupations, and Other occupations (typically non-doctoral occupations) (Vitae 2010c).

'What do researchers do? Career paths of doctoral graduates' (Hodges et al. 2011) used the occupational clusters to examine the mobility of doctoral graduates by mapping the pathways of doctoral graduates within and between the clusters.

The HESA data, although very informative, are limited to the early careers of doctoral graduates i.e. up to 4 years after graduation. There have been several studies on the longer term trajectories of doctoral graduates' careers; however these have tended to focus on specific cohorts or small samples (Innes and Feeney 2012; STFC 2010; Wellcome Trust 2009). Research Councils UK commission a study (Research Councils UK 2014) to examine the economic impact of doctoral graduates 7–9 years after graduation, particularly those employed outside higher education. The survey achieved a 4 % response rate, half of whom were employed in higher education. Overall, we lack a comprehensive view of the longer term career paths of researchers.

At the time of writing, Vitae is undertaking a European research project, in partnership with NatureJobs, Science Europe and LERU on the career paths of doctoral graduates who have undertaken a period of postdoctoral research in higher education or research institutes and have subsequently moved into non-academic occupations. 'What do research staff do next?' is a qualitative study that will use narratives to describe the career decisions of researchers who move out of higher education research, how they managed the transition, their current occupations, and satisfaction with their career. As there are no registers or databases of these researchers, and they are known to be difficult to reach, Vitae is using a social media approach to reach out to these researchers. Through a combination of articles, blogs, newsletters, Twitter and using academic and researcher networks and communities who may know researchers who have moved out of higher education research, we are extensively disseminating information on the project and requests to participate in the survey.

Through such a combination of methods, we aim to build as full a picture as possible about the careers of doctoral holders both in the UK and internationally. Forty stories illustrating the transition of research staff into other occupations have been published on the Vitae website https://www.vitae.ac.uk/researcher-careers/researcher-career-stories

12.5.3 The Vitae Impact Framework for Researcher Development

In parallel with the significant investment of UK public money in the Roberts agenda to improve the employability and careers of researchers being trained in UK HEIs, the need to account for and evaluate the impact of such an investment arose.

Vitae (then working as the UK GRAD Program) convened a sector-based working group which explored the strategies by which UK stakeholders and the HE sector could monitor and evaluate the impact of the Roberts agenda. In 2008, a specially designed impact framework was published (Bromley et al. 2008), based on the Kirkpatrick evaluation model (Kirkpatrick 2006). Rather than seeking to define a series of easy-to-measure simplistic metrics, this 2008 framework proposes a more thoughtful evaluation approach. It was felt to be most appropriate to measure not only the growth in infrastructure and support, but also the learning acquired by individual researchers, how that impacted their behaviour, and whether those behavioural changes then led to any discernibly different outcome in terms of their research, careers, or lives (Fig. 12.4).

Furthermore, rather than requiring each individual research organization to report separately and fully at all the potential levels of evaluation, it was agreed that Vitae, by introducing a common framework, would seek to then provide a meta-analysis of evaluation and research findings to build a broad picture of the likely impact across the UK.

In 2010, an update was published which highlighted the progress made in the 2 years since the Impact Framework was released (Bromley 2010) and referenced 120 examples of evaluation projects. In 2012, the Impact Framework was again updated to include much of the learning gained through the use of the Impact Framework since 2008 as well as actual case studies which provided evidence of the multi-level impacts of the Impact Framework (Bromley and Metcalfe 2012):

> Emergent case studies gathered from across the sector in 2010 provided strong evidence that researcher development activity was capable of impacting in many key areas including, maximising the investment in research, impacting on research practice, culture and the researcher experience, significant impact on employability of researchers, and life-changing personal impact for individual researchers (p 1).

The report concludes:

> The Impact and Evaluation Group supports the continued growth of researcher development scholarship and research to maintain and increase the academic rigour of evaluation of researcher development activities. This is to enable increased understanding of

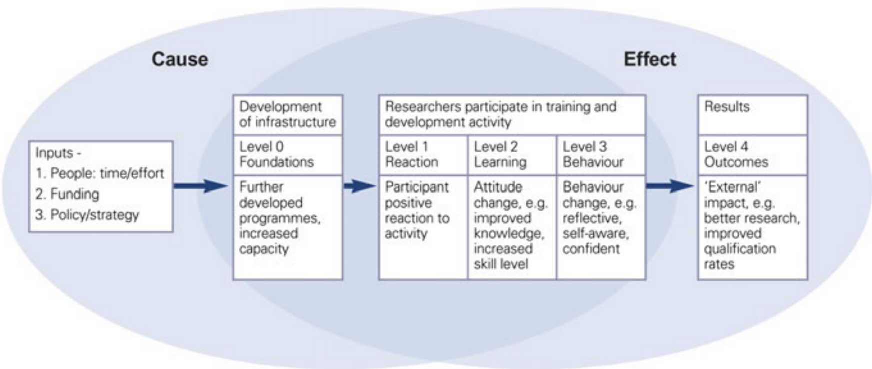

Fig. 12.4 The Vitae Researcher Development Impact Framework (Bromley et al. 2008)

evaluation methodology and impact, which in turn will contribute to enhancing researcher development training and development activity (p 11).

As the world devotes increasing attention to how and why we train doctoral researchers, the corresponding evaluation frameworks and research are critical to ensure that researcher development remains relevant, cost-effective, and able to deliver tangible results.

References

Bennett P, Turner G (2013) Pres 2013: results from the postgraduate research experience survey. Higher Education Academy

Bentley K, Hooley T (2010) What do researchers do? Career profiles of doctoral entrepreneurs, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-career-profiles-of-doctoral-entrepreneurs-vitae-2010.pdf. Accessed 27 Oct 2014

Bray R, Boon S (2011) Towards a framework for research career development: an evaluation of the UK's Vitae Researcher Development Framework. Int J Res Dev 2(2):99–116, Emerald

Bromley T (2010) The impact of researcher training and development: two years on. Impact and Evaluation Group, Cambridge. ISBN 978-1-906771-14-1

Bromley T, Metcalfe J (2012) The impact framework 2012: revisiting the rugby team impact framework: evaluating and exploring the evidence of the impact of training and development activities for researchers. Careers Research and Advisory Centre (CRAC) Limited, Cambridge

Bromley T, Metcalfe J, Park C (2008) The rugby team impact framework. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. ISBN 978-1-906774-00-4

CRAC (2006) The research career mapping tool report. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. http://www.grad.ac.uk/downloads/documents/Reports/RCMT/RCMT%20Project%20Report%20March%2006.pdf. Accessed 14 Sept 2014

Haynes K (2010) Analysis of university reports on career development and transferable skills training (Roberts) payments. Research Councils UK, Swindon. http://www.rcuk.ac.uk/RCUK-prod/assets/documents/skills/Analysis20042009RobertsReports.pdf. Accessed 22 Sept 2014

Haynes K, Metcalfe J, Videler T (2009) What do researchers do? First destinations of doctoral graduates by subject, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-wdrd-by-subject-vitae-jun-2009.pdf. Accessed 27 Sept 2014

HESA (2014) Students in higher education 2012/13. https://www.hesa.ac.uk/publications-and-products?task=show_pub_detail&pubid=1

Hill S, Turton K, White H (2014) Published at the Vitae international researcher development conference, Manchester, 2014. http://www.hefce.ac.uk/media/hefce/content/news/events/2014/understanding-transition-to-doctoral-study.pdf. Accessed 14 Sept 2014

Hodge A (2010) Review of progress in implementing the recommendations of Sir Gareth Roberts, regarding employability and career development of PhD students and research staff: a report for Research Councils UK by an Independent Review Panel. Research Councils UK, Swindon. http://www.rcuk.ac.uk/RCUK-prod/assets/documents/skills/IndependentReviewHodge.pdf. Accessed 22 Sept 2014

Hodges V, Metcalfe J, Pollard E (2011) What do researchers do? Career paths of doctoral graduates, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-career-paths-vitae-2011.pdf. Accessed 27 Sept 2014

Hooley T, Videler T (2009) What do researchers do? Career profiles of doctoral graduates, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-wdrd-career-profiles-vitae-jun-2009.pdf. Accessed 27 Oct 2014

Hunt W, Jagger N, Metcalfe J, Pollard E (2010) What do researchers do? Doctoral graduate destinations and impact three years on, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-wdrd-3-years-on-soft-copy-vitae.pdf. Accessed 27 Sept 2014

Innes P, Feeney D (2012) Career paths of AHRC funded PhD students. http://www.ahrc.ac.uk/News-and-Events/Publications/Documents/Career-Pathways-Final-Report-PhD.pdf. Accessed 22 Sept 2014

Kirkpatrick DL (2006) Evaluating training programmes, 3rd edn. Berrett-Koehler Publishers, Oakland, CA. ISBN-10: 1-57675-384-4; ISBN-13: 978-1-57675-384-4

Leitch S (2006) Prosperity for all in the global economy—world class skills, HM Treasury. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228853/0118404792.pdf (executive summary only), http://dera.ioe.ac.uk/6322/1/leitch_finalreport051206.pdf (full report). Accessed 14 Sept 2014

Mellors-Bourne R, Jackson C, Hodges V (2012) What do researchers want to do? The career intentions of doctoral researchers. Careers Research and Advisory Centre (CRAC) Limited, Cambridge

Mellors-Bourne R, Metcalfe J, Pollard E (2013) What do researchers do? Early career progression of doctoral graduates, Cambridge, Careers Research and Advisory Centre (CRAC) Limited as part of the 'What do researchers do?' series by Vitae. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-early-career-progression-2013.pdf. Accessed 27 Oct 2014

Mellors-Bourne R, Metcalfe J, Pearce E, Hooley T (2014) Understanding the recruitment and selection of postgraduate researchers by English higher education institutions. Higher Education Funding Council for England

Metcalfe J (2012) A pan-European professional development framework for researchers: a feasibility study by the ESF Member Organisation Forum European Alliance on Research Career Development. European Science Foundation, Strasbourg, http://www.esf.org/fileadmin/Public_documents/CSSD/MO_Fora/ESF_RDF_pilot_report_310812_final.pdf. Accessed 21 Sept 2014

Pearce E (2014) MRC Gambia Unit, Researcher Development Programme: overall programme evaluation. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. http://www.esf.org/fileadmin/Public_documents/CSSD/MO_Fora/ESF_RDF_pilot_report_310812_final.pdf. Accessed 1 May 2016

Quality Assurance Agency (2011) Doctoral degree characteristics. http://www.qaa.ac.uk/en/Publications/Documents/Doctoral_Characteristics.pdf. Accessed 14 Sept 2014

Quality Assurance Agency (2012) UK quality code for higher education. Chapter B11: research degrees. http://www.qaa.ac.uk/publications/information-and-guidance/publication?PubID=175#.VE4t7xhFDcs. Accessed 27 Oct 2014

Reeves J, Denicolo P, Metcalfe J, Roberts J (2012) The Vitae Researcher Development Framework and Researcher Development Statement: methodology and validation report. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. https://www.vitae.ac.uk/vitae-publications/rdf-related/researcher-development-framework-rdf-vitae-methodology-report-2012.pdf. Accessed 14 Sept 2014

Research Councils UK (2013) Statement of expectations for doctoral training, Swindon. http://www.rcuk.ac.uk/RCUK-prod/assets/documents/skills/statementofexpectation.pdf. Accessed 22 Sept 2014

Research Councils UK (2014) The impact of doctoral careers. http://www.rcuk.ac.uk/RCUK-prod/assets/documents/skills/timodcfullreport.pdf. Accessed 8 Apr 2015

Reynolds J, Leslie G, Mitchell A (2013) RDF Planner Pilot Evaluation. Careers Research and Advisory Centre (CRAC) Limited, Cambridge, https://www.vitae.ac.uk/vitae-publications/rdf-related/researcher-development-framework-rdf-planner-evaluation-pilot-vitae-2013.pdf/view. Accessed 27 Oct 2014

Roberts G (2002) SET for success. http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/d/robertsreview_introch1.pdf

SGHRM, Steering Group on Human Resources and Mobility (2014) Report of the 2014 SGHRM WG on Professional Development of Researchers. http://ec.europa.eu/euraxess/pdf/research_policies/Final%20Report%20of%20the%20ERA-SGHRM%20WG%20on%20Professional%20Development%20of%20Researchers%202014.pdf. Accessed 9 Apr 2015

STFC, Science and Technology Facilities Council (2010) A Study of the career paths of PPARC/STFC funded PhD students. https://www.stfc.ac.uk/resources/pdf/CPFR.pdf. Accessed 22 Sept 2014

Vitae (2010) Vitae Researcher Development Framework. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. https://www.vitae.ac.uk/rdf. Accessed 14 Sept 2014

Vitae (2010a) Vitae Researcher Development Statement. Careers Research and Advisory Centre (CRAC) Limited, Cambridge. https://www.vitae.ac.uk/rds. Accessed 14 Sept 2014

Vitae (2010b) What do researchers do? Doctoral graduate destinations and impact three years on, Methodology. https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-wdrd-methodology-vitae-16-dec.pdf

Vitae (2012–2014) Vitae Researcher Development Framework lenses (various). Careers Research and Advisory Centre (CRAC) Limited, Cambridge. www.vitae.ac.uk/rdflenses. Accessed 21 Sept 2014

Warry P (2006) Improving the economic impact of the Research Councils. http://www.rcuk.ac.uk/Publications/archive/TheWarryReport/. Accessed 14 Sept 2014

Wellcome Trust (2009) Basic science career tracker. http://www.wellcome.ac.uk/Funding/Biomedical-science/Career-tracker/Basic-tracker/index.htm

Willey N, Spencer P (2014) Using 'research-based learning' to enhance doctoral skills development published by Vitae in Vitae Occasional Papers: Volume 1: The impact of researcher development—a collection of papers based on workshops at the Vitae Researcher Development International Conference, 3–4th September 2013, Manchester, UK. https://www.vitae.ac.uk/vitae-publications/reports/vitae-conference-occasional-papers-vol-1-2014.pdf/view. Accessed 27 Oct 2014

Domestic and International Destinations of Japan's Doctorate Holders

13

Toshiyuki 'Max' Misu and Akira Horoiwa

13.1 Introduction

In a knowledge-based economy with increasing R&D investment, the success of innovation relies on nurturing and securing highly trained and skilled talents within a global domain. Accordingly, the number of researchers has increased from 6.6 per 1,000 employees in 1999 to 7.6 per 1,000 in 2009 in the OECD area, and more new doctorate holders have been produced in the same decade (OECD 2011). The increase in the production of highly educated human resources in science and technology reflects concerns about scientific labor force shortages that were predicted for several OECD member countries in the early 1990s based on assumptions of increasing future demand for engineers and scientists and declining student interest in science and engineering (OECD 1991).

In Japan, the massive expansion of graduate education in the 1990s led to a large increase in the number of students entering graduate programs at both master's and doctoral levels. In recent years, Japan has produced about 16,000 doctoral graduates annually. However, the number of students entering doctoral programs reached its peak in 2003 and then started to decline. Similarly, the number of newly awarded doctorates, which roughly doubled in the past three decades, also started to decline after 2006. In order for Japan to maintain its international competitiveness, strengthening the educational utility and attractiveness of its doctoral programs via qualitative improvements is more important than ever. In addition, Japan's graduate schools are now expected to train highly

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skilled personnel, with both deep expertise and broad versatility, who can take an active role not only in academia but also in industry. However, the imbalance between the number of doctorate holders produced and the availability of independent research positions has become more apparent in recent years. Although the number of university teachers hired has gradually increased, it has been surpassed by the number of doctoral graduates since 1997, indicating that the chance of obtaining an academic research position is becoming slimmer for recent doctoral graduates. Recent doctoral graduates face the increasing duration of the postdoctoral training period and the difficulty in finding stable research positions.

In addition to the larger supply of doctorate holders in recent years, there have also been some changes affecting the employment system of university teachers. In 1997, the fixed-term employment system for university teachers was introduced to revitalize university education and research, and induce knowledge-fusion by promoting the mobility of academic researchers. It is expected that the mobility of university teachers can stimulate academic knowledge exchange and interactions between academic researchers with different backgrounds, which can be effective in enhancing their education and research capabilities. In particular, from the viewpoint of developing young faculty members, there is a recognition that engagement in education and research in different institutions through the introduction of a fixed-term employment system is benefits young researchers by giving them 'Musha-shugyo' (Knight-errantry) experience and career development.

Furthermore, the environment surrounding the national university has changed greatly since its incorporation in 2004. Basic policies for structural reform adopted by the Cabinet in 2006 indicated year-on-year budget subsidies for operating expenses of the national university (nominal value) to be reduced by 1 %. As the results show, subsidies for operating expenses decreased from 1.22 trillion yen in FY2006 to 1.16 trillion yen in FY2010. Although the reduction policy was abolished in the budget for FY2010, subsidies for operating expenses have been reduced to 1.08 trillion yen in FY2013. For national universities where subsidies for operating expenses have been reduced, reliance on external funds including competitive funds has increased annually. There are concerns that reducing subsidies for operating expenses and diversifying competitive funds may have some negative effects on research activities: examples of possible negative consequences on research include the choice of research topics that can deliver results in a short period of time, greater inequalities between universities of different sizes in their capability to obtain external funding, and decreasing the time available for research associated with the need to spend longer on securing competitive funding, etc.

Similarly, in 2006, an administrative reform was implemented that aimed to reduce—within 5 years—the total sum of personnel expenses, such as the staff of the national university corporation to higher than 5/100ths equivalency sum of the amount in 2005. According to the survey,[1] many universities introducing the personnel expenses reduction policy intend to defer recruiting new teachers,

[1] See http://www.zam.go.jp/n00/pdf/ni004001.pdf (in Japanese).

supplementing retired faculty members as a countermeasure to the total personnel expenses reform. In addition, deferred retirement of university teachers started in 2004, which will possibly make it harder for young researchers to acquire tenure in academia.

Owing to various factors such as decreases in subsidies for operating expenses, reforms of personnel expenses, deferred retirement age and increase in fixed-term employment, the time taken for young researchers to obtain tenured academic positions is greater than before. Now, approximately a quarter of postdoctoral researchers have been in unstable, postdoctoral research positions for more than 5 years (Misu et al. 2008), and the average age of assistant professors is increasing. It is often claimed that these changes may also have led to a reduction of talented students entering doctoral courses owing to uncertain career prospects.

For careers outside of academia, the main destination for doctorate holders is research and development (R&D) in the business enterprise sector. In Japan, researchers in the business enterprise sector are the main actors of the country's R&D activities. In 2012, 75 % of research personnel (FTE) belonged to the business enterprise sector. However, only 4 % of researchers employed in the business enterprise sector hold a doctoral degree—a ratio that has not changed for decades.[2] The longitudinal study 'Survey on Research Activities of Private Corporations' has been conducted annually by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) since FY1968 and shows recurring trends of researchers in business enterprise with R&D activities (NISTEP 2011a). The FY2011 survey results show that the average number of newly hired researchers per company was 9.3 persons per company, whereas that of newly hired researchers with doctoral degrees was only 0.3 persons per company. Indeed, the majority of newly hired researchers in the business enterprise sector are those with a master's degree. Although the business enterprise sector may have an absorption capacity in hiring more doctorate holders as R&D personnel, doctorate holders are not yet considered the main actors of business R&D activity. It has been claimed that there are quality mismatches in terms of doctorate holders' competencies: companies perceive doctorate holders as lacking communication skills and cooperativeness.[3]

Nevertheless, when doctorate holders are hired in the business enterprise sector, employers seem satisfied with their overall abilities. In a recent MEXT survey (2009), employers were asked what competencies they would emphasise or expect most from employees hired as R&D personnel with a bachelor's or master's degree a doctoral qualification, or postdoctoral research experience. Among 11 competencies, 'Problem setting and solving skills' and 'Capacity to think logically' are valued most by employers, irrespective of education or training background (bachelor's or master's degree, doctorate, or postdoctoral research). In most cases, those with postdoctoral research experience are expected to possess

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[2] Based on the Survey of Research and Development by the Ministry of Internal Affairs and Communications Statistics Bureau (http://www.stat.go.jp/english/data/kagaku/index.htm)

[3] http://www.keidanren.or.jp/japanese/policy/2007/020/chosa-kekka.pdf (in Japanese).

higher competencies than those holding other degrees. Competencies that employers seek most are 'Sense of responsibility/sociality' for bachelor degree holders, 'Problem setting and problem solving skills' for master's degree holders, and 'In-depth knowledge of area of expertise' for doctoral graduates and postdoctoral researchers. Employers were also asked about the competencies of hired R&D personnel in terms of their educational or training background. In general, the share of those rated as 'above expectation' is higher for those with postdoctoral research experience, followed by doctoral graduates, master's degree holders, and finally, by bachelor degree holders. Employers valued the ability to make presentations as 'above expectation' for holders of a bachelor's degree, master's degree, and doctoral graduates. In contrast, employers most valued postdoctoral researchers for their ability 'to think logically'. The competency that employers valued as 'below expectation' was 'originality' for bachelor's and master's degrees holders as well as doctoral graduates, whereas for postdoctoral researchers this was the 'ability to manage progress'.

Despite increasing attention to the diversification of career paths, including non-academic and/or non-research careers, little is still known about where and how doctorate holders apply their acquired knowledge and skills and how their careers develop after completing doctoral programs.

Lastly, another major aspect of highly skilled human resources in science and technology relates to mobility. The transfer and diffusion of knowledge through mobile human resources, especially from doctorate holders, and moving across jobs, institutions and countries are also considered key drivers of innovation. The international mobility of highly skilled talent can contribute to the creation of new networks and the diffusion of knowledge across borders. With the increasing internationalisation of education, research and innovation, the competition to attract highly skilled talents has become more intense than ever. In the case of researchers, it is also argued that internationally mobile researchers are more productive than non-mobile counterparts (Horoiwa et al. 2008). To increase the international competitiveness of its research system, Japan needs to be recognised as part of the mainstream international brain circulation. However, there are some concerns that Japan's research personnel remains isolated from this phenomenon.

When it comes to welcoming inward-bound overseas talent, the number of overseas researchers accepted in Japanese universities and research institutes for longer than 1 month increased until FY2000 and then remained roughly constant (MEXT 2012). To attract world-class foreign researchers, MEXT launched the World Premier International Research Centre Initiative (WPI) in 2007 with the goal of creating 'internationally visible' research centres with higher research standards and an outstanding research environment, so as to attract top researchers from around the world. By FY2012, nine WPI centres were selected in Japan. All five centres selected in FY2007 have a high share of foreign researchers, ranging from 30 to 50 % of total researchers. Accordingly, these five WPI centres have shown a remarkable performance in terms of productivity: they are second for the productivity of the top 1 % of papers and fifth for the average number of citations.

On the other hand, the number of highly skilled Japanese researchers who go overseas to work for longer than 1 month has been declining since FY2000 (MEXT 2012). In FY2000, this number was about 7,700 people while in FY10, it had decreased to about 4,300 people. However, there was no available data regarding the number of Japanese doctorate holders and/or researchers who actually find employment overseas.

13.2 Quantitative Evidence on the Careers of Japan's Doctorate Holders

As discussed above, it is important to understand how effectively Japan fosters highly skilled human resources through its doctoral education programs, and efficiently the country delivers those human resources to both domestic and global labor markets. There is almost no national survey that quantitatively captures the careers of Japan's doctorate holders. Neither the Population Census nor the Labor Force Surveys can identify individual educational attainment levels separating master's and doctoral degrees. Only a few national surveys collect a limited volume of quantitative data on doctorate holders with almost no career information: (a) the School Basic Survey, carried out annually by the Ministry of Education, Culture, Sports, Science and Technology since 1948, captures the first career destinations of doctoral graduates without identifying their locations and tenure status[4]; (b) the Survey of Research and Development by the Ministry of Internal Affairs and Communications Statistics Bureau collects only the total number of doctorate holders working as researchers without any other demographic information[5]; and (c) the Survey on Research Activities of Private Corporations carried out by the Ministry of Education, Culture, Sports, Science and Technology which identifies the total number of doctoral graduates and postdoctoral researchers newly hired as research personnel without any other demographic details.[6]

While doctorate holders are expected to be mobile, especially early on in their career, there has been no quantitative evidence tracking their early careers. In 2008, a full-scale survey was launched for the first time in Japan—the 'Career Trends Survey of Recent Doctoral Graduates'. This survey aimed to reveal the diversity of career paths and the status of international mobility among all doctoral graduates from Japanese universities during FY2002–2006 (NISTEP 2009).[7] It was conducted as part of the follow-up to Japan's Third Science and Technology Basic Plan and aimed at contributing to the establishment of the Fourth Basic Plan. The survey targeted all doctoral graduates (including those who withdrew upon obtaining the required credits) from Japanese universities during

[4] See http://www.mext.go.jp/b_menu/toukei/chousa01/kihon/1267995.htm (in Japanese).

[5] See http://www.stat.go.jp/english/data/kagaku/index.htm

[6] See http://www.mext.go.jp/b_menu/toukei/chousa06/minkan/1267231.htm (in Japanese).

[7] See http://data.nistep.go.jp/dspace/bitstream/11035/661/1/NISTEP-NR124-FullE.pdf, pp. 77–84.

FY2002–2006 and collected data on individual characteristics (sex, age, nationality, research field, type of financial support and experience during doctoral education, etc.) and career paths (occupation, location, affiliation, etc.) as of April 2008. All the 414 universities that were asked to participate in the survey responded. Data were collected on 75,197 individuals who completed doctoral courses. Questionnaires were sent to all universities offering doctoral courses in Japan. The survey collected data on individual characteristics and the career paths of first and current (as of April 2008) destinations (occupation, employment sector, location, and type of contract).

Because the first and current (as of April 2008) career destinations of all doctoral graduates are unknown for about 23 % and 47 % of the sample respectively, unknown data on the first place of work were first replaced with known values from those of a similar group in terms of student type (general/foreign/adult students), university type (four categories), gender and age group (34 years old or under/35 years old or more). Next, unknown data on the current career destination were replaced with known values of a similar group using 10 variables including the first destination data (occupation, employment sector, location, and type of contract). After all the replacements were completed, data on the careers of recent graduates who withdrew upon obtaining the required credits without receiving a doctoral degree were excluded from the dataset for the present analysis. In this chapter, we explain the global destinations of Japan's doctorate holders based on this modified dataset submitted to the OECD for better international comparability.

Before discussing the domestic and the international destinations of Japan's doctorate holders in the following sections, we show their overall career destinations. As shown in Fig. 13.1, the number of doctoral graduates, i.e. those with and without doctoral degrees, increased from 13,712 in FY2002 to 16,589 in FY2006, and about 73 % of doctoral graduates (FY2002–2006) received doctoral degrees. In the following, we only focus on those with doctoral degrees, i.e. doctorate holders, in accordance with the OECD's CDH Guidelines (Auriol et al. 2012).

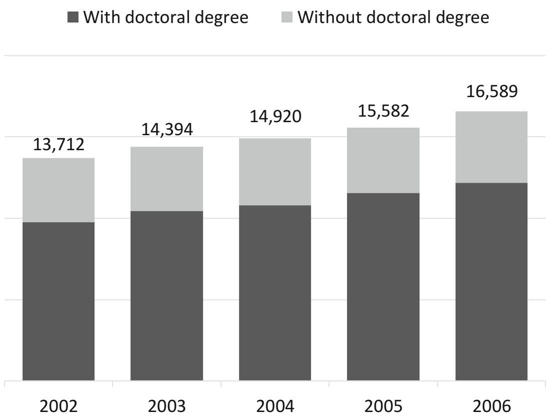


Fig. 13.1 Number of recent doctoral graduates with and without doctoral degrees who completed doctoral courses in FY2002–2006. *Source*: Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

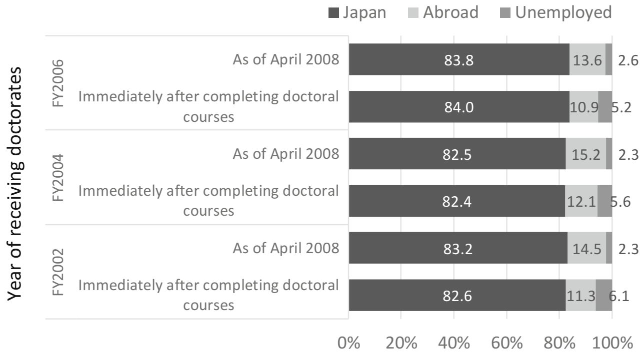


Fig. 13.2 Locations of doctorate holders immediately after completion of doctoral courses and locations as of April 2008 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

Figure 13.2 shows the locations of all doctorate holders immediately after completing doctoral courses and their current locations in April 2008. Here, 'unemployed' includes students and homemakers. Immediately after completing their doctoral courses, 82–84 % of Japan's doctorate holders remained in Japan, while 11–12 % moved abroad. One to five years after completing their doctoral courses, 83–84 % of doctorate holders had found jobs in Japan as of April 2008, while the share of those working abroad increased to 14–15 %. The locations of doctorate holders stay roughly the same, irrespective of the year of receiving their doctorates and the time since graduation.

In the following, we first focus on doctorate holders currently residing in Japan (as of April 2008) to understand their domestic labor market situation, and then discuss the characteristics of Japanese doctorate holders' international mobility from a global perspective.

13.3 Domestic Destinations of Japan's Doctorate Holders

The labor market situation for doctorate holders is expected to differ depending on career stage. For recent doctoral graduates in their early career especially, career prospects are greatly influenced by the massive expansion of higher education in the 1990s, the limited number of available tenured research positions in academia and the constantly changing demand for skills in the labor market in recent years. The increasing duration of the postdoctoral training period and the difficulty in finding positions for young researchers have also become major obstacles for recent doctoral graduates, and potentially lead to the declining attractiveness of research careers and doctoral studies. These factors give rise to concerns about the quality of doctoral students and young researchers in some countries (OECD 2007; OSTP

2004). In this regard, the labor market situation at the early career stage may also have direct consequences for long-term outcomes and thus determine the future course of innovation activities.

In addition, there have been increasing concerns over mismatches between the skills of recent doctoral graduates and the skills required by employers, in terms of doctoral graduates acquiring transferable skills and applying their specialised knowledge in a practical environment (Roberts 2002). As science and technology progress rapidly, doctoral training alone cannot cover the broad range of knowledge and skills needed to carry out cutting-edge research. Additional research experience and training schemes during the postdoctoral phase thus play a crucial role in preparing young researchers for a professional research career and improving their marketability. In this regard, understanding the employment trends of recent doctoral graduates is essential in terms of evaluating the effectiveness of current doctoral training programs and subsequent postdoctoral experiences, implementing appropriate policy measures, and promoting a variety of initiatives to enhance career support activities for young researchers, including training to nurture transferable skills.

In this section, we examine the careers of recent graduates who resided in Japan at the time of the survey, and we discuss in detail some questions of policy relevance. What share of doctorate holders move into academic careers and/or careers outside of academia? How long does it take for them to obtain a stable research position? What are the employment situations of doctorate holders in terms of time since graduation or field of doctoral study?

Figure 13.3 shows the career-path diversity of doctorate holders in the early career stage who were residing in Japan as of April 2008. How many recent doctorate holders are employed as researchers and how many can be counted as postdoctoral researchers? Because the definition of postdoctoral researcher varies across countries, we steered away from defining postdoctoral researchers. Instead, we define 'temporary (postdoc-type) researcher' as doctorate holders who obtained a doctoral degree within the past 5 years and are employed in a temporary research position. About 70 % of recent doctorate holders are employed as researchers in Japan. The share of temporary researchers is higher for recent graduates, and the ratio of being a postdoc-type (temporary) researcher reaches 32 % 1 year after completing doctoral courses in FY2006. Although doctorate holders eventually obtain a permanent research position, the proportion of researchers with temporary contracts still remains at 23 % even 5 years after completing doctoral courses. It is clear that a higher share of postdoc-type employment can explain the higher employment rates for recent graduates; postdoctoral appointments may play a buffer role in providing doctorates with employment opportunities when there is seemingly a shortfall in regular employment compared to doctorate production.

As shown in Fig. 13.3, the research and development (R&D) activities in Japan depend on young talent in postdoc-type positions, and also raise the question of how the share of postdoc-type researchers influences research activity and productivity. Some studies suggest that postdoctoral researchers contribute substantially to the production of papers as first authors and/or highly cited papers (NISTEP 2011b)

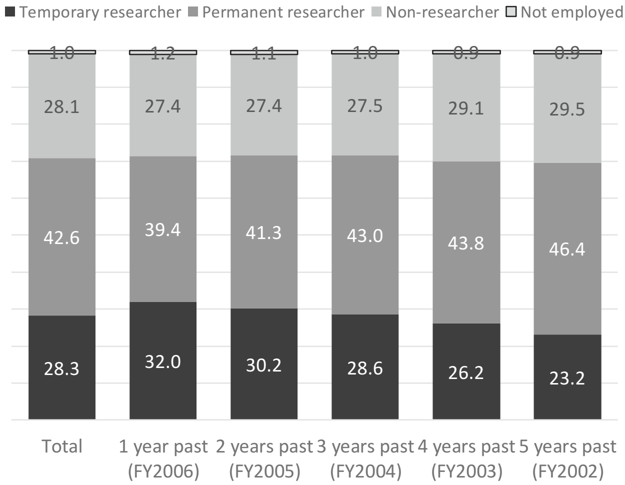


Fig. 13.3 Current career destinations of recent doctorate holders residing in Japan by time elapsed since receiving their doctoral degrees (as of April 2008). *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

and that past postdoctoral experience also leads to higher scientific outputs (Horta 2009).

From the perspective of early career researchers, the career path from unstable postdoctoral employment to tenured position is rife with uncertainties. How many recent doctorate holders obtained permanent research positions? Obviously, the probability of obtaining a permanent research position depends on the sector of employment and the field of doctoral study. Figure 13.4a demonstrates the sector of current employment for doctorate holders engaged in research. While the main sector of employment for doctorate holders working as a researcher is the higher education sector, 27 % of doctorate holders in early research careers also find employment opportunities in the business enterprise sector. By comparing three main employment sectors for recent doctorate holders (Fig. 13.4b), the share of permanent contracts for researchers is more than twice as high in the business enterprise sector relative to the higher education sector, indicating that postdoc-type employment is not commonly adapted in the business enterprise sector. The shares of those employed in the higher education and government sectors are below 50 %, which may indicate a competitive academic environment.

In terms of the field of doctoral study, 1–5 years after completing doctoral courses, 74 % of engineers found permanent research positions, whereas more than half of natural scientists, agricultural scientists, and those specialising in humanities were still employed in temporary research positions (Fig. 13.5).

In general, the career destinations and employment situations of recent doctorate holders vary greatly across fields of doctoral study. For instance, Fig. 13.6 illustrates the results using a more detailed field classification on the careers of

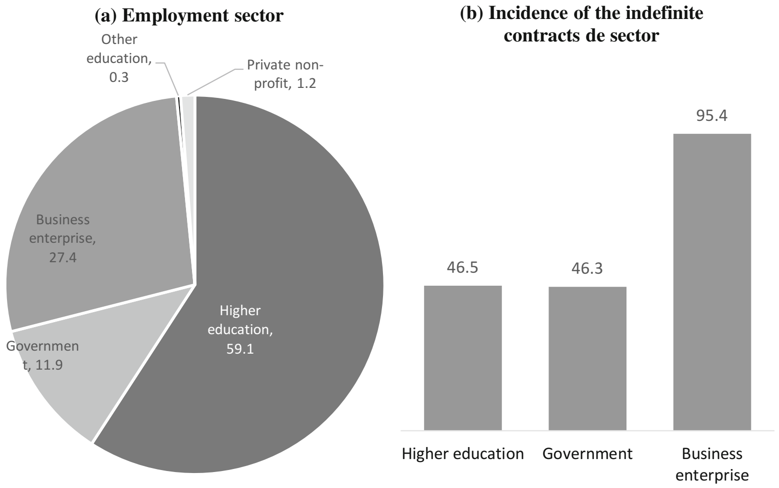


Fig. 13.4 Current employment sector and contract type (as of April 2008) of recent doctorate holders working as researchers in Japan who received doctoral degrees during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

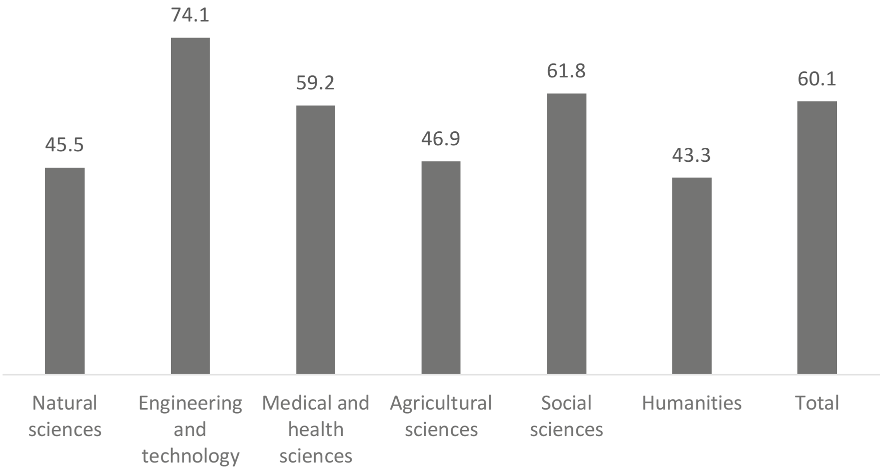
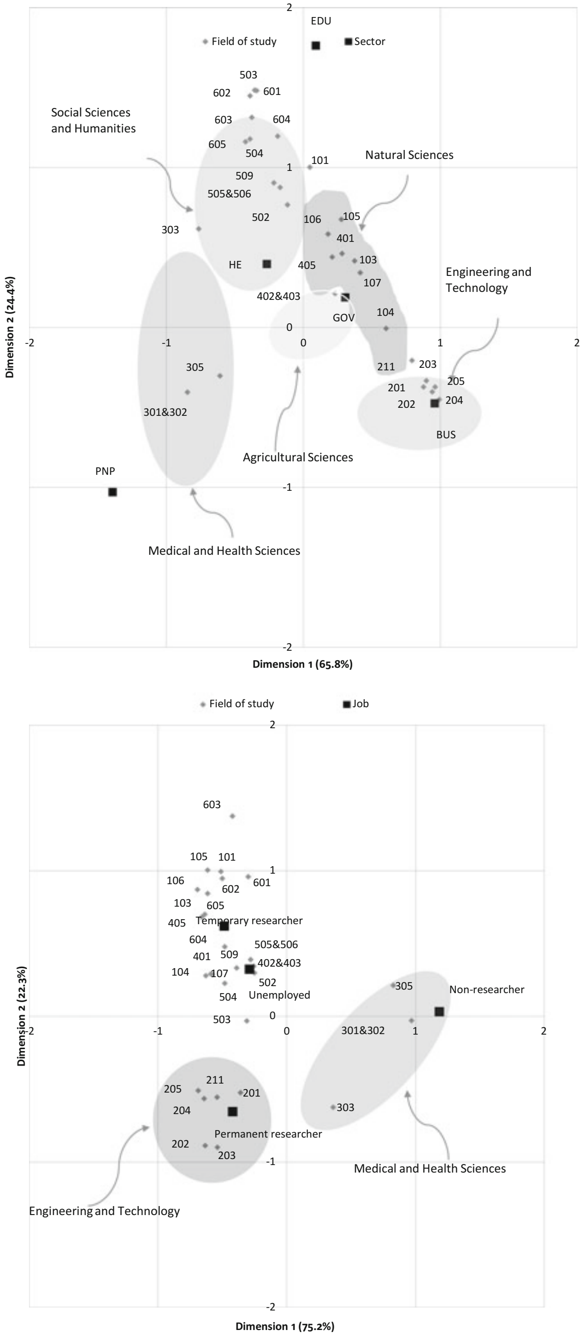


Fig. 13.5 Incidence of indefinite contracts of recent doctorate holders engaged in research in Japan as of April 2008, by field of doctoral study (as a percentage of employed doctorate holders with known research status) as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

Fig. 13.6 Career destinations of doctorate holders who completed doctoral courses during FY2002–2006 and currently reside in Japan as of April 2008, by field of doctoral study. *Note*: Sector of employment 'BUS', 'GOV', 'HE', 'EDU' and 'PNP' correspond to the 'business', 'government', 'higher education', 'other education' and 'private non-profit organization' sectors, respectively. Sector and field are approximately matched with the categories given in the OECD's CDH model questionnaire. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP2009) produced for the OECD activity on Careers of Doctorate Holders



doctorate holders who reside in Japan. In the correspondence analysis, the distance between variables indicates the closeness of their relationship.

Overall, career destinations are very much clustered around aggregated fields of doctoral study. Regarding sector of employment (Fig. 13.6a), engineers are clustered around the business enterprise sector (denoted by 'BUS'), whereas medical scientists are allocated between private non-profit organizations (denoted by 'PNP') and the higher education sector (denoted by 'HE'). The sector of employment for those specialising in social sciences and humanities is closer to the higher education and other education sectors (denoted by 'EDU'), while agricultural scientists are mostly employed in the higher education and government (denoted by 'GOV') sectors. Although natural scientists are mostly employed in the higher education and government sectors, mathematicians (denoted by '101') are closer to the other education sector, and chemical scientists (denoted by '104') are employed more in the business enterprise sector than other natural scientists. Subsequent interviews with university faculty members that we undertook pointed to three factors regarding the differences in career destinations between chemical scientists and other natural scientists: (1) chemical science research in academia is rather similar to research within industry; (2) chemical science laboratories often collaborate with and/or receive R&D funds from industry; and (3) graduates of chemical sciences find more employment opportunities in the business sector since chemical- and material-related research is actively carried out in a wide range of industrial sectors (MISU et al. 2010).

Interestingly, the separate survey on the employment status of postdoctoral researchers affiliated with universities and public research institutions in Japan identified which specific research fields are more closely linked to the business sector. It did this by counting the number of all postdoctoral researchers whose laboratory engaged in joint research with and/or received R&D funds from industry, as illustrated in Fig. 13.7. The closest ties with industry are depicted for most of the engineering fields (nearly 70 %), followed by health sciences and chemical sciences (approximately 60 %). Other natural sciences, including biological sciences, have ratios of less than 40 %.

Apparently, a stronger link between university and industry research is expected to affect the career outcomes of doctoral graduates. For instance, recent doctorates who obtained financial support from and/or were trained (or did an internship) in the private sector during their doctoral studies are found to have a higher probability of obtaining a job in the business sector (Recotillet 2007; NISTEP 2009).

Furthermore, employing doctoral holders in firms results in the establishment and/or strengthening of collaboration between the firms and other R&D organizations, leading to technology transfer and further stable collaborations (Cruz-Castro and Sanz-Menéndez 2005).

Contrary to the wider career paths observed for chemical scientists, some biology specialists have been facing stagnated demand from the business sector, although the prioritised funding schemes for life science-related research have provided young graduates with employment opportunities as postdoctoral researchers. Similarly, in the United States it is often argued that increased funding

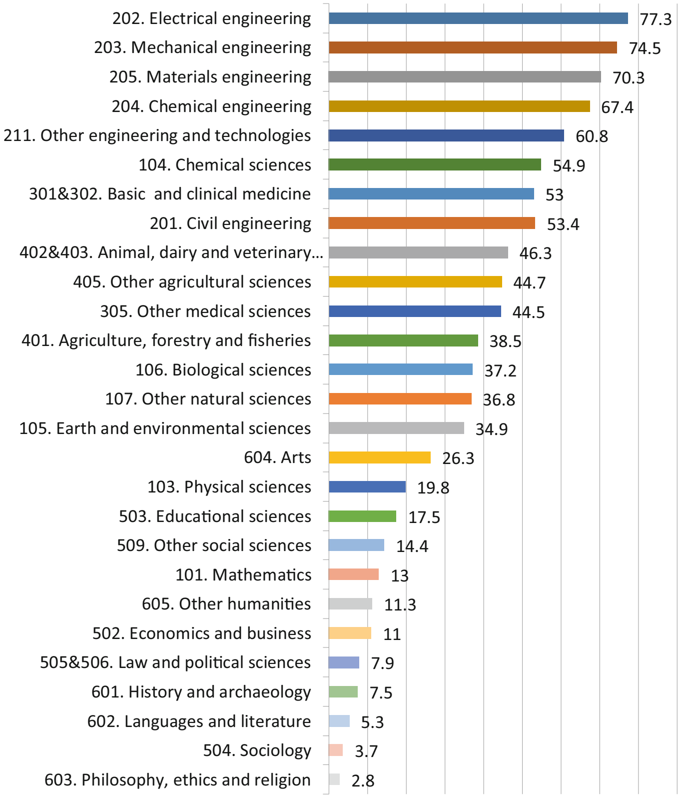


Fig. 13.7 Ratio of postdoctoral researchers whose laboratory engaged in joint research with and/or received R&D funds from industry, by field of research, 2009 as a percentage. *Note*: Some fields are approximately matched with the categories given in the OECD's CDH model questionnaire. *Source*: Based on 'Survey on Postdoctoral Fellows (FY2009 data)' (NISTEP 2011c)

for life science research has led to greater production of doctorates and postdoctoral researchers in biological sciences than actual employment to meet the demand (Goldman and Massy 2000).

In terms of the type of job contract (Fig. 13.6b), engineers tend to be employed as permanent researchers, while those who specialise in medical and health sciences are more likely to find non-research jobs. Doctorate holders with specialisations in natural sciences, agricultural sciences, and humanities tend to become temporary researchers, as previously discussed.

Another question is what share of doctorate holders move into non-research careers? In a knowledge-based society, although the increasing role of doctorates in non-research careers is expected, little is known as to how those in non-research positions apply their knowledge and skills gained through doctoral training. As already illustrated in Fig. 13.3, irrespective of the time since graduation, close to one-third of doctorate holders are currently employed as non-researchers (as of

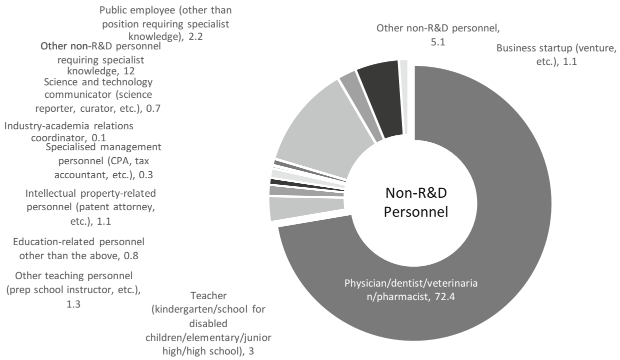


Fig. 13.8 Current jobs (as of April 2008) of recent doctorate holders working as non-researchers in Japan who received doctoral degrees during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

April 2008). The top non-research job by far for doctorate holders is a physician/dentist/veterinarian/pharmacist, which is the main destination for those who specialise in medical and health sciences, as shown in Fig. 13.8. This is the reason for medical scientists to be employed as non-researchers in the private non-profit organization sector. Among non-researchers, only 3 % of non-researchers became a teacher at K12 level. Although recent science and technology policy in Japan does address the issue of promoting diversity in career paths for doctorate holders, it is clear that non-research career options are still limited in Japan, except for those who specialize in medical and health sciences.

13.4 International Mobility of Japan's Recent Doctorate Holders

This section aims to clarify the career trends in international mobility of doctorate holders who completed doctoral courses in Japan by analysing the 'Career Trends Survey of Recent Doctoral Graduates'. From the results of this survey, we can understand the features of doctorate holders who go abroad after completing doctoral courses in Japan, and the role they play in global brain circulation. The study shows that the international mobility of recent doctorate holders in Japan mainly consists of two streams of brain circulation: one in which foreign doctoral students from Asia return to their home countries, and the second in which Japanese graduates move to the United States as postdoctoral fellows and eventually return to Japan.

Which countries are the main overseas destinations for Japan's doctorate holders? Figure 13.9 shows the top 10 overseas destinations of Japan's doctorate holders immediately after completing doctoral courses in FY2006. China is the leading overseas destination, followed by the United States, indicating that the

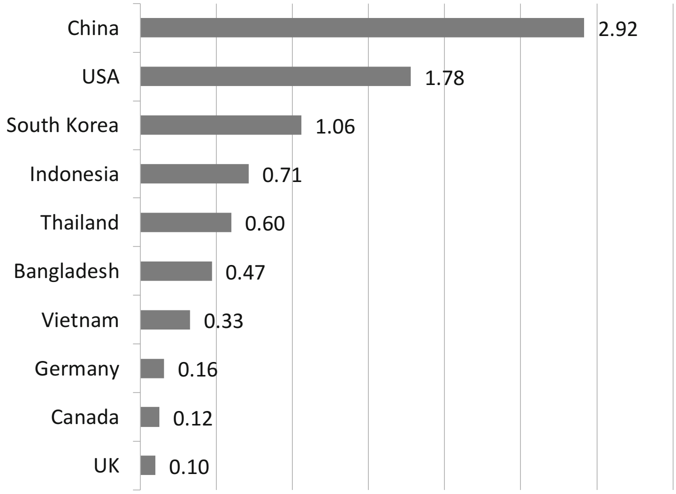


Fig. 13.9 Top 10 overseas destinations of employed doctorate holders from Japan immediately after completion of doctoral courses (as a percentage of all doctorate holders who graduated in FY2006). *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

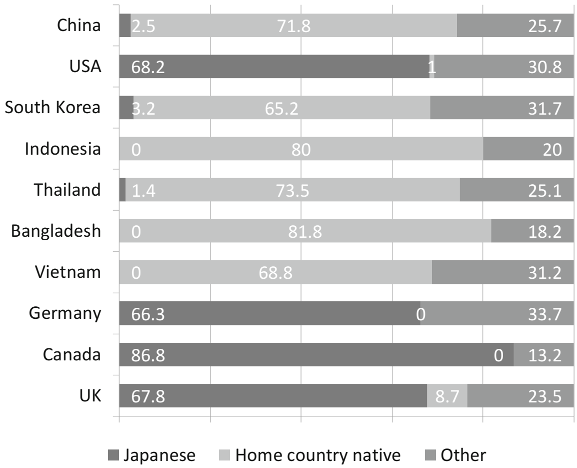


Fig. 13.10 Overseas destinations and nationalities of employed doctorate holders immediately after completion of doctoral courses in FY2006 by the top 10 overseas destinations (as a percentage of each destination). *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

outward flows from Japan are mainly directed towards the Asian region and the United States. However, two groups of Japan's internationally mobile doctorate holders, namely Japanese and foreign doctorates, show different mobility patterns. Figure 13.10 shows the rates of 'Japanese', 'home country natives' (people returning to their home countries), and 'others' by the top 10 overseas destinations. The majority of those who moved to Asian countries were 'home country natives', while those who moved to Western countries were mainly Japanese and other foreign nationals. This illustrates the two typical international mobility patterns for doctorate holders in Japan: one in which foreign doctorates return to their home countries, and a second in which Japanese doctorates move to the United States and other Western countries. Therefore, these two groups must be considered separately.

13.4.1 International Mobility of Japan's Foreign Doctorate Holders

We first discuss Japan's foreign doctorate holders, especially Asian international students. We divide them into 'China' (students from China), 'South Korea' (from South Korea), 'other Asia' (from all Asian countries excluding China and South Korea), and 'others'. Next we examine the yearly trend of foreign doctoral holders immediately after completion of doctoral courses during FY2002–2006 (Fig. 13.11). Japan has been attracting doctoral students from the Asian region, in particular from China and South Korea. The share of those coming from South Korea has decreased, while the number of those coming from other Asian region is increasing over time.

We have already seen the nationality of Japan's doctorate holders by the top 10 overseas destinations in Fig. 13.10. By focusing on the locations of the foreign doctorate holders immediately after completion of doctoral courses in Japan, we

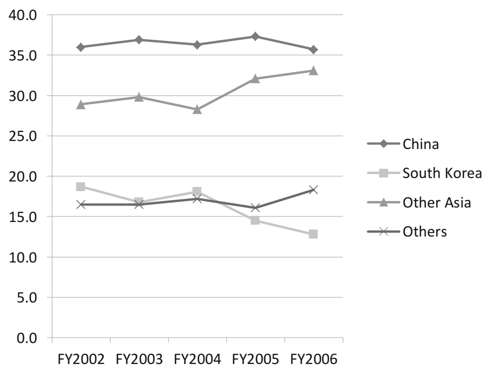


Fig. 13.11 Nationalities of doctorate holders who completed doctoral courses during FY2002–2006 (as a percentage of all foreign doctorate holders) as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

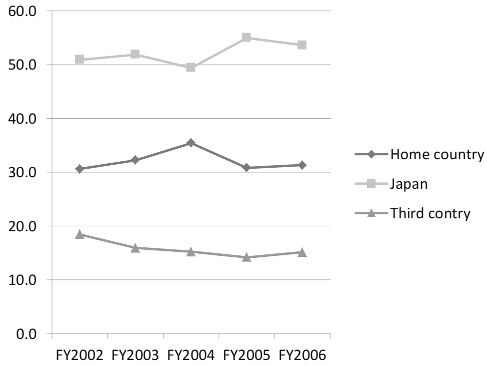


Fig. 13.12 Locations of employed foreign doctorate holders immediately after completing doctoral courses during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

examine whether they remained in Japan, returned to their home countries,[8] or moved to a third country. Figure 13.12 below shows the trend of the ratio of these three mobility patterns during FY2002–2006. In FY2006, 54 % of them remained in Japan immediately after completion, while 31 % returned to their home countries and 15 % moved to a third country. Comparing FY2000 with FY2006, the ratio of foreign doctorate holders who remained in Japan has gradually increased, while the ratio of those who moved to a third country has decreased. For those returning to their home countries, the ratio has remained at roughly 31 % except in FY2004.

As a group of highly skilled foreign workers, foreign doctorate holders who remain in Japan are expected to make the greatest contribution to Japan's long-term economic growth through innovative R&D activities. By measuring the stay rates of foreign doctorate holders in Japan, we can also identify the current capacity of domestic labor markets to absorb them and their roles in Japanese society. In this context, the United States has been successful in attracting highly skilled foreign talent. For example, in the United States, immigrants started about half of the technology firms in Silicon Valley and also comprise about half of the science and engineering personnel with PhDs (Wadhwa et al. 2007). In Japan, the stay rate of foreign doctorate holders immediately after completion is about 50 %. Although such a simple comparison between the United States and Japan is ambiguous owing to the different methodologies used to estimate the stay rates, comparatively speaking, the estimated stay rate (ratio of intention to stay) of foreign doctorate holders with temporary visas was more than 20 % higher in the United States than in Japan during the same period (NSF 2006). On the other hand, foreign doctorate

[8] 'Home country' here is not exactly equivalent to 'countries' in the strict sense, because the survey only allowed the respondents to choose major countries. Minor countries were categorised into regions and 'other countries' (such as those in Africa and Oceania) were treated collectively. Therefore, 'return to home country' also includes foreign doctorate holders returning to their area of origin.

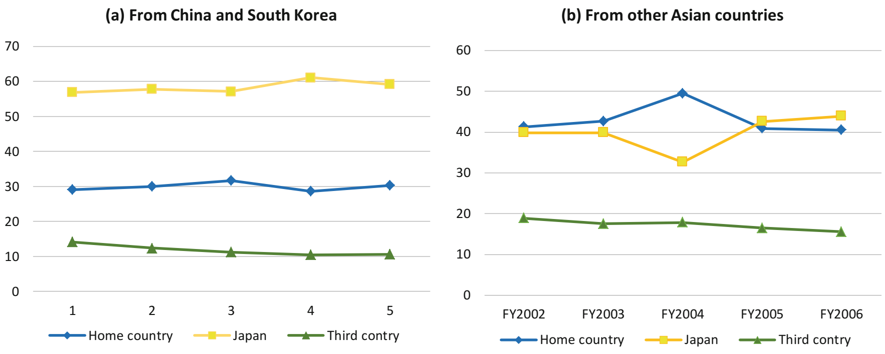


Fig. 13.13 Locations of foreign doctorate holders from (**a**) China and South Korea and (**b**) other Asian countries immediately after completing doctoral courses during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

holders in Japan have a greater tendency to leave the host country: the percentage of foreign doctorate holders who moved out of Japan is roughly 50 %, whereas the proportion of recent foreign doctorate holders who have declared an intention to leave the United States and Canada is about 40 % (Auriol 2007).

We now discuss the relationship between the nationality of foreign doctorate holders and their destinations immediately after completion. Who stays in Japan, and who are the returnees? Figure 13.13 illustrates the locations of foreign doctorate holders (a) from China and South Korea, and (b) from other Asian countries immediately after completing doctoral courses during FY2002–2006. The ratio of Chinese and South Korean doctorate holders who remained in Japan exceeds that of the returnees, whereas for doctorate holders from other Asian countries the ratio of returnees was about the same as those who stayed in Japan, with the exception of FY2004.

In addition, we also focus on the role of foreign doctorate holders in each destination by looking at their occupations, as demonstrated in Fig. 13.14. Accordingly, 67 % of the returnees and 58 % of those who moved to the third countries obtained permanent research positions. On the other hand, when foreign doctorate holders remain in Japan, they mostly contribute to Japan's R&D activity as temporary researchers such as postdocs (60 %).

What motivates foreign doctorate holders to remain in Japan or return to their home countries? Our limited number of interviews with Japanese university faculty members following this survey indicated that some foreign doctorate holders, especially those from China, may have faced difficulties in obtaining university faculty positions in their home countries in recent years. Those capable of reading and writing the Japanese language have a greater chance of being hired in Japan (Misu et al. 2010). The increase of these Asian doctorate holders who remain in

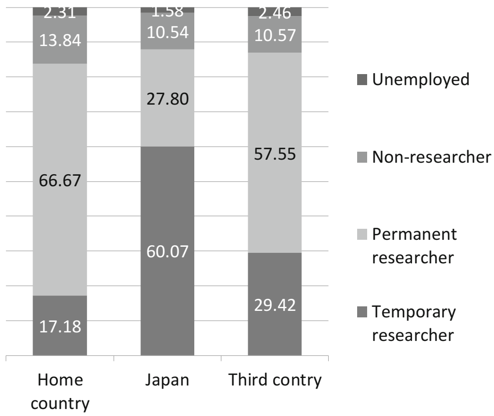


Fig. 13.14 Locations and occupations of foreign doctorate holders immediately after completing doctoral courses during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

Japan immediately after completing doctoral courses may also be explained by the labor market situation in their home countries. In addition, a Japanese doctoral degree may—to some extent—be losing value as a 'ticket' to obtain a university faculty position in their home countries. In studies of the United Kingdom (Baruch et al. 2007) and the United States (Wadhwa et al. 2009), the decisions of highly educated foreigners to remain in the host country or return to their home countries are likely to be affected by career opportunities and labor markets, adjustment to the host country, family ties, etc. However, further study of foreign doctorate holders in Japan is needed to clarify the key factors determining whether a foreign doctorate holder stays or returns because our interviews indicate other possible factors such as inadequate research environments in their home countries.

For other Asian doctorate holders who returned to their home countries, our limited interviews revealed that the majority of those graduates already held university faculty positions in their home countries prior to coming to Japan, and returned to their former work after completing doctoral courses in Japan (Horoiwa et al. 2010).

The nature of Japan's foreign doctorate holders' international mobility is mainly characterised by two phenomena: Japan's brain gain of Asian doctorate holders who remain in Japan, and contributions to Asian countries through brain circulation.

13.4.2 International Mobility of Japanese Doctorate Holders

In this section, we discuss the second group—Japanese doctorate holders who moved overseas. According to the OECD database on immigrants and expatriates (OECD 2005), Japan has quite a low expatriation rate of its highly skilled native-born population relative to other OECD countries. Connected with this, there have been increasing concerns that young researchers including doctoral students are not willing to go abroad, and that Japan may be left out from the mainstream international brain circulation. However, before our survey, no solid evidence was available for assessing the recent trends regarding the international mobility of doctorate holders.

As shown in Fig. 13.15, the ratio of Japanese doctorate holders who found employment abroad after completing doctoral courses is only approximately 3 % of all Japanese doctorate holders, and it remained substantially unchanged during FY2002–2006. This implies that the international mobility of Japanese doctorate holders is quite low and very limited.

Figure 13.16 below highlights the main overseas destinations of Japanese doctorate holders who completed doctoral courses in FY2006. The top overseas destination is the United States followed by Canada and European countries, indicating that destinations of Japanese doctorate holders are limited to the most developed countries.

As already discussed with regard to foreign doctorate holders, we now turn to look at the role of Japanese doctorate holders in Japan and abroad. Depending on the destination, the types of job that Japanese doctorate holders obtained differ substantially. According to Fig. 13.17, 78 % of Japanese doctorate holders who moved overseas took temporary research positions, while the occupations of those finding domestic employment seem more evenly distributed. In particular, the ratio of those becoming overseas temporary researchers is considerably higher than that of those staying in Japan (33 %). In other words, we see that most Japanese doctorate holders who move overseas immediately after completing doctoral courses take temporary research jobs such as postdocs in the United States.

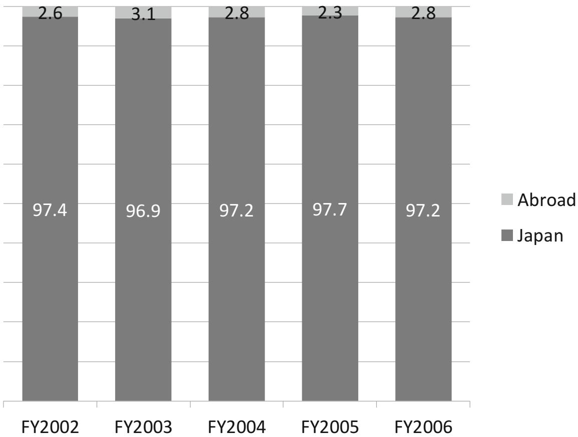


Fig. 13.15 Locations of employed Japanese doctorate holders immediately after completing doctoral courses during FY2002–2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

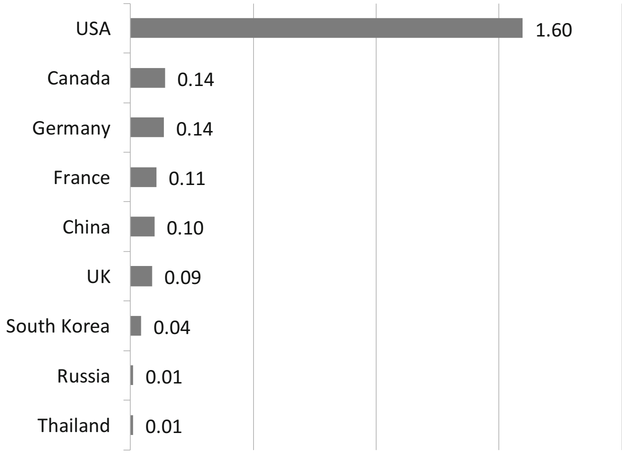


Fig. 13.16 Main overseas destinations of Japanese doctorate holders immediately after completing doctoral courses in FY2006 (as a percentage of all Japanese doctorate holders). *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

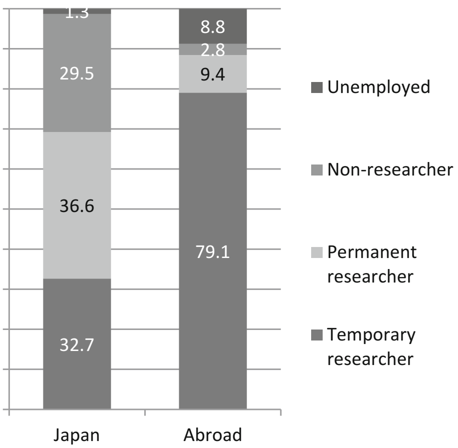


Fig. 13.17 Occupations of Japanese doctorate holders by locations immediately after completing doctoral courses in FY2006 as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

Although we did not carry out a follow-up survey about the career paths of these Japanese doctorate holders who completed doctoral courses and immediately moved overseas, we can identify their current locations as of April 2008. Among the Japanese doctorate holders who completed doctoral courses between FY2002 and FY2006 and immediately moved overseas, Fig. 13.18 below illustrates the

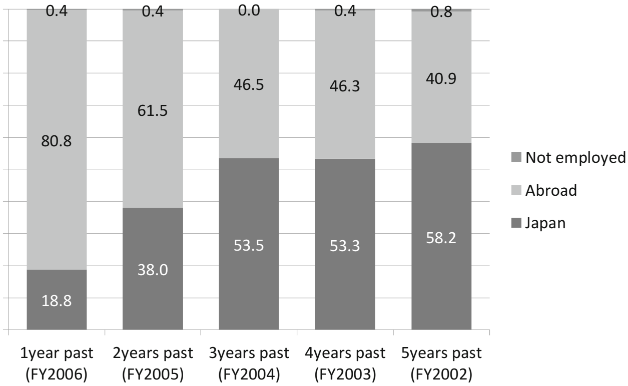


Fig. 13.18 Current locations (as of April 2008) of Japanese doctorate holders who found employment overseas immediately after completing doctoral courses during FY2002–2006 (as a percentage of all Japanese doctorate holders who moved overseas immediately after completion). *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

percentages of those returning to Japan and those staying abroad 1–5 years after completion. The ratio of those who returned to Japan increased each year after completing Japanese graduate courses. In particular, 58 % of those who had completed their doctoral courses 5 years earlier were back in Japan. This suggests that the international mobility of Japanese doctorate holders is temporary, and that most of those who undertake overseas postdoctoral training return to Japan within several years.

13.5 Conclusion and Policy Implications

In this chapter, we examined both the domestic and the international destinations of Japan's recent doctorate holders who completed doctoral courses in Japan during FY2002–2006.

While it now takes longer for early career researchers to obtain tenured academic positions for a variety of factors such as the decrease in subsidies for operating expenses and total personnel expenses, the introduction of postdoc-type positions in the labor market have provided new doctorate holders with more employment opportunities and has thus improved their employment rates. It may also act as a buffer when there is a shortfall in regular employment compared to the supply of new doctorates. However, this type of employment potentially creates higher competition and uncertain career prospects for those employed in the higher education sector, as concern about temporary positions for new doctorates appears to be much more concentrated within this sector. The results clearly highlight that academic research depends on young talent in postdoc-type positions. Thus, further investigation into the role and effects of postdoctoral research experience on future career outcomes and productivity must be carried out.

We also observed strong links between the field of specialisation and employment sector. It can be inferred that a closer connection between universities and industries through collaboration and R&D funding schemes potentially helps to diversify the career paths of doctorate holders, including non-academic career paths such as academic laboratories with few connections to non-academic sectors. In addition to collaborative research with industry, providing various opportunities to doctoral students to work with the business enterprise sector (such as internships) may also help to diversify their career options. As indicated in Fig. 13.19, doctorate holders who have completed an internship during their doctoral education tend to be employed in the business enterprise sector more than those who have not done an internship. In this respect, Japan's Ministry of Education, Culture, Sports, Science and Technology has run various programs since FY2006 to promote the diversity of career paths for young researchers, including funding for long-term internships aimed at doctoral students and postdocs. Rather than being limited solely to improving the career prospects of doctorate holders, the next step of government policy should be to focus on training and using doctoral students and postdocs as innovators by inducing close interactions between education, research, and innovation.

We also looked at the international mobility patterns of Japan's recent doctorate holders. We showed that there are two trends of international mobility of foreign doctorate holders (Fig. 13.20). Chinese and South Korean doctorate holders are more likely to stay in Japan than return to their home countries, while other Asian doctorate holders tend to move back to their home countries. Although the share of foreign doctoral graduates who stay in Japan after graduation may not be as high as

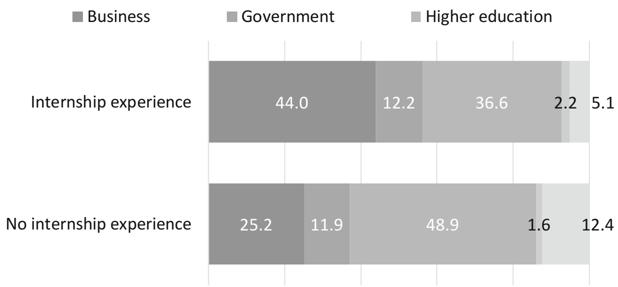
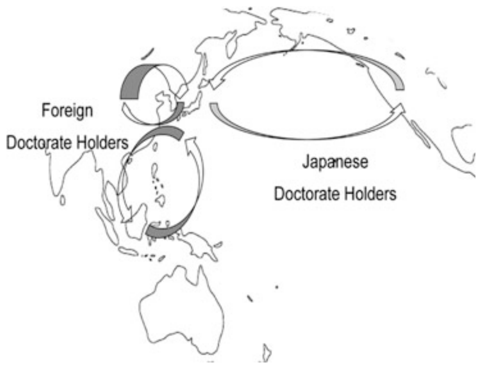


Fig. 13.19 Sector of employment of Japan's doctorate holders immediately after completing doctoral courses for those with and without an internship experience during their doctoral degree (for all doctorate holders who graduated during FY2002–2006) as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

Fig. 13.20 Schematic overview of the international mobility of Japan's doctorate holders



in the United States, Chinese and South Korean doctorate holders who remained in Japan are expected to contribute to Japan's R&D activity largely through being temporary researchers. In addition, Japan's doctoral courses attract researchers from the entire Asian region and play an important role in contributing to brain circulation across Asia. Many people from the Asian region have held university faculty positions in their home countries and return to those positions (or institutions) after finishing their doctorate in Japan.

Complementary to the Japanese government's '300,000 Foreign Students Plan' which aims to more than double the number of foreign students in Japan to 300,000 by 2020,[9] some graduate schools in Japan have begun offering new English-language courses, in which students can acquire a degree without acquiring proficiency in Japanese. Offering courses of this type certainly satisfies the needs of non-Japanese Asian students, and is expected to strengthen the brain circulation of highly skilled talent throughout the Asian region.

On the other hand, only approximately 3 % of all Japanese doctorate holders found employment abroad after completing doctoral courses, implying that the international mobility of Japanese doctorate holders is limited. However, these internationally mobile Japanese doctorate holders may play an active role in short-term brain circulation by returning to Japan after postdoctoral training overseas. Future research should assess the trends over time and evaluate the effects of this brain circulation of Japanese doctorate holders.

In parallel with internship opportunities, providing overseas research experience during doctoral education may also encourage doctoral students to go abroad after

[9] The measures of this program includes (1) offering incentives to study in Japan and providing one-stop service, (2) improving introduction of entrance examinations, enrollment, and entry into Japan, (3) promoting globalization of universities and other educational institutions (e.g. studying only in English), (4) improving the environment for accepting international students, and (5) promoting acceptance of international students in society after their graduation or completion of courses (MEXT 2008).

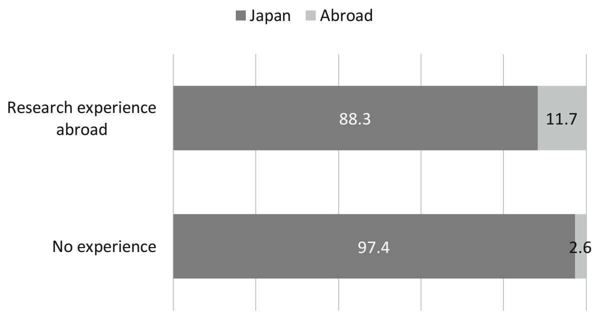


Fig. 13.21 Locations of Japan's doctorate holders immediately after completing doctoral courses by research experience abroad during doctoral education (for all doctorate holders who graduated during FY2002–2006) as a percentage. *Source:* Based on ad hoc tabulations of 'Career Trends Survey of Recent Doctoral Graduates' (NISTEP 2009) produced for the OECD activity on Careers of Doctorate Holders

completing doctoral courses. Indeed, more Japanese graduates with research experience in foreign institutions during their doctoral education tend to move overseas immediately after completing doctoral courses (Fig. 13.21). Given this fact, it is important to create an environment that will promote further international mobility of Japanese doctoral students to overcome the present stagnation regarding the international experiences of doctorate holders in Japan.

References

Auriol L (2007) Labour market characteristics and international mobility of doctorate holders: results for seven countries. OECD Science, Technology and Industry working paper 2007/2. DSTI/DOC. OECD Publishing, Paris

Auriol L, Schaaper M, Felix B (2012) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators, 3rd edn. OECD Science, Technology and Industry working papers 2012/07. OECD Publishing, Paris. doi:10.1787/5k4dnq2h4n5c-en

Baruch Y, Budhwar PS, Khatri N (2007) Brain drain: inclination to stay abroad after studies. J World Bus 42:99–112

Cruz-Castro L, Sanz-Menéndez L (2005) The employment of PhDs in firms: trajectories, mobility and innovation. Working paper 05-07. CSIC

Goldman CA, Massy WF (2000) The PhD factory: training and employment of science and engineering doctorates in the United States. Anker Publishing, Bolton, MA

Horoiwa A, Misu T, Tsunoda H (2008) Survey on research activities and attitudes of postdoctoral fellows. Research material 159. National Institute of Science and Technology Policy, Tokyo [in Japanese]

Horoiwa A, Misu T, Chayama H (2010) Analysis on the international mobility of doctoral graduates in Japan. Research Material 180. National Institute of Science and Technology Policy, Tokyo [in Japanese]

Horta H (2009) Holding a post-doctoral position before becoming a faculty member: does it bring benefits for the scholarly enterprise? High Educ 58:689–721

Ministry of Education, Culture, Sports, Science and Technology (MEXT) (2008) Outline of the student exchange system: study in Japan and abroad. http://www.mext.go.jp/a_menu/koutou/ryugaku/081210/001.pdf
Ministry of Education, Culture, Sports, Science and Technology (MEXT) (2009) Survey on research activities of private corporations [in Japanese]
Ministry of Education, Culture, Sports, Science and Technology (MEXT) (2012) Survey results on international research exchange for FY2010 [in Japanese]
Misu T, Horoiwa A, Tsunoda H (2008) Investigative survey on the research activities and awareness of postdoctoral fellows: analysis on career choices of postdoctoral scholars. Research material 161. National Institute of Science and Technology Policy, Tokyo [in Japanese]
Misu T, Horoiwa A, Chayama H (2010) Career paths of recent doctoral graduates in science. Research material 184. National Institute of Science and Technology Policy, Tokyo [in Japanese]
National Institute of Science and Technology Policy (NISTEP) (2009) Career trends survey of recent doctoral graduates. NISTEP report 126. National Institute of Science and Technology Policy, Tokyo [in Japanese]
National Institute of Science and Technology Policy (NISTEP) (2011a) Survey on research activities of private corporations (2011). NISTEP report 152. NISTEP, Tokyo [in Japanese]
National Institute of Science and Technology Policy (NISTEP) (2011b) Knowledge creation process in science: key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech scientists' survey in Japan and the US. Research material 203. NISTEP, Tokyo [in Japanese]
National Institute of Science and Technology Policy (NISTEP) (2011c) Survey on postdoctoral fellows regarding employment and moving-out situations (FY2009 Data). Research material 202. NISTEP, Tokyo [in Japanese]
National Science Foundation (NSF) (2006) Survey of doctorate recipients: 2006. National Science Foundation, Arlington
OECD (1991) Science and technology policy: review and outlook. OECD Publishing, Paris
OECD (2005) OECD Science, Technology and Industry scoreboard 2005—towards a knowledge-based economy. OECD Publishing, Paris
OECD (2007) Summary report of the Joint OECD-Spanish Ministry of Education and Science workshop on research careers for the 21st century. OECD Publishing, Paris
OECD (2011) OECD Science, Technology and Industry scoreboard 2011. OECD Publishing, Paris
Office of Science and Technology Policy (OSTP) (2004) Sustaining the nation's innovation ecosystem: maintaining the strength of our science and engineering capabilities. President's Council of Advisors on Science and Technology
Recotillet I (2007) PhD graduates with post-doctoral qualification in the private sector: does it pay off? Labour 21(3):473–502
Roberts G (2002) SET for success: the report of Sir Gareth Roberts' review
Wadhwa V, Rissing B, Saxenian A, Gereffi G (2007) Education, entrepreneurship and immigration: America's new immigrant entrepreneurs, Part II. Duke University, UC Berkeley and Ewing Marion Kauffman Foundation
Wadhwa V, Saxenian A, Freeman RB, Gereffi G (2009) America's loss is the world's gain: America's new immigrant entrepreneurs, Part 4. Duke University, UC Berkeley and Ewing Marion Kauffman Foundation

The 'Added Value' of Researchers: The Impact of Doctorate Holders on Economic Development

14

Adriana Bin, Sergio Salles-Filho, Fernando A. Basile Colugnati, and Fábio Rocha Campos

14.1 Introduction

This manuscript provides an exploration of the professional trajectories of doctorate holders in an emergent economy. It presents an analysis of original data from more than 4,000 PhDs[1] in Brazil and examines it from the perspective of the country's research and innovation situation. The manuscript is intended to address two main areas of interest: the ways in which an emergent country with around 13,000 PhDs graduating per year is creating advanced capabilities; and the economic and social impacts of these trends.

Fostering research training, mainly through the PhD degree, has been an important feature of science, technology and innovation (ST&I) policies around the world since the 1950s. From the policy perspective, qualified researchers are seen as a means to widen innovation capacity as well as to improve economic and social wellbeing. From the individual perspective, achieving a PhD is seen traditionally as

[1] While PhD is not the only path to gaining a doctoral level qualification, it is the most traditional form. This manuscript will therefore refer to doctorate holders, doctoral graduates and PhDs interchangeably.

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a path to an academic career or to a research career in the private or public sector, as well as a way to fulfill one's own personal interest and curiosity.

In modern knowledge-based economies, where research and innovation are important drivers of economic expansion, human capital—and particularly a highly educated workforce (including those with a doctoral education)—is acknowledged as one of the prerequisites for economic development and growth (Leitch 2006; Halse and Mowbray 2011; Salter and Martin 2001; Tremblay 2005; Neumann and Tan 2011).

While doctoral education is still seen as a key component of ST&I policies, the changing nature of job markets poses some challenges to ensuring that investment in PhDs delivers the expected positive outcomes. In a number of countries, supply of doctoral graduates exceeds demand for them. In itself this situation is not uncommon: except in conditions of full employment, some degree of unemployment is always present. Notwithstanding, it is worth noticing that since the 1990s the world has seen an increase in the number of doctorate enrollments and graduates, and at the same time a relative slowing down of recruitment of researchers, particularly in academic jobs (Mangematin 2000; Zusman 2005; Taylor 2011; Cyranoski et al. 2011; Neumann and Tan 2011).

This situation suggests a mismatch between human capital formation and research and innovation capacity, fueling the debate about the role of public funding in professional researchers' education and their social and economic impacts (Enders 2002; Auriol et al. 2012). Indeed, the general debate about the economic benefits of research—including the provision of trained research personnel and their implications for public policy (Pavitt 1991; Salter and Martin 2001)—has become increasingly focused on highly skilled graduates and the changing landscape of the labor market.

The consequences of this changing landscape are twofold. From the supply side, it is necessary to rethink policies and PhD programs to adjust them to this new reality. This involves both curricular and institutional changes, which can bring a combination of new knowledge promotion and a focus on practical problems, with a closer alignment between the skills developed in doctoral programs and the need of industry and other non-academic sectors, in a more diverse and multi-faceted model (Taylor 2011; Halse and Mowbray 2011; Kobayashi 2011). However, as pointed out by Enders (2002), discussions about the reorganization of doctoral education are dominated by controversial debates on the extent to which higher education should reorganize to change its modes of knowledge production (e.g. creating more applied and interdisciplinary knowledge). From the demand side, the situation suggests the need to facilitate the development of the PhD labor market through incentives to retain high-qualified researchers in different sectors and roles.

Tracking the career destinations of doctorate holders is a good way to better understand this situation in different regions and countries, therefore enabling policy design, both from the supply side (doctoral programs) and from the demand side (academia, industry, government and other sectors). This kind of initiative is traditionally under-researched when compared to studies on undergraduates as presented by Raddon and Sung (2009). Nevertheless, the research and higher education agencies of several countries have conducted such studies to measure the multidimensional impacts of research and researchers, as a way to account for the public investments in this area and to support future efforts.

Some empirical work in this area has been produced in the last few decades, discussing the impacts of PhD training policies in important dimensions (e.g. employment, mobility, skills generation, self-satisfaction, rewards, collaboration). However, few of them analyze these features against the backdrop of more comprehensive indicators on innovation and economic growth at the national or even the regional level. In addition, there is an evident lack of studies discussing this changing landscape in less developed and non-OECD countries.

The aim of this paper is to contribute to filling this gap by providing an investigation of the impact of doctoral training on the subsequent careers of PhDs in Brazil. Some selected studies on doctoral education and their economic benefits are presented in the second section, forming the background for discussion of the Brazilian case. The third section explains the research methods and tools employed in our case study, while the fourth section presents the main findings and discussion. Finally, the last section presents some general conclusions, as well as an agenda for future studies.

14.2 Prior Literature

There have been many studies in recent years on the impact of doctoral education on the economy and society. Discussing the contribution that publicly funded research has on economic growth, Salter and Martin (2001) emphasize that the capacities and knowledge background of skilled graduates is a distinctive benefit of publicly funded research. Such graduates are oriented towards solving complex problems, performing research and developing ideas.

Casey (2009) distinguishes several benefits of doctoral education: the individual private returns from the possession of a PhD qualification, commonly reflected in higher wages; the contribution of doctorate holders to increasing the pool of knowledge; the teaching/learning effects associated with their engagement in the higher education sector; the potential transfer of new knowledge to industry and consequent contribution to the next generation of new or improved products, processes and services; and finally the spillovers of the ‘embodied’ knowledge of PhDs in the work environment e.g. creativity, problem solving skills, hypothetical thinking. This last type of contribution is similar to Cohen and Levinthal’s (1989) concept of ‘absorptive capacity’, understood as the role of R&D in enhancing a firm’s ability to assimilate and exploit existing information. Other authors such as Lee et al. (2010), Tremblay (2005), Neumann and Tan (2011), Cruz-Castro and Sanz-Menéndez (2010) and Connor and Brown (2009) also discuss these kinds of impacts. Roach and Sauermann (2010) and Garcia-Quevedo et al. (2012), in their work on PhDs engaged in firms, also note the impact of PhDs in creating favorable environments for R&D and enhancing their firms’ participation in external networks with the scientific community. Although most research has focused on the economic effects of PhDs, Raddon and Sung (2009) suggest the importance of other wider social impacts such as political engagement, community development and cultural contributions.

In spite of this diversity in the perceived impacts of PhDs and the importance of doctoral education, some effects are difficult to quantify. Connor and Brown (2009) claim that evidence linking graduates' employment and their skills with economic performance are problematic, mainly because skills are just one factor among many that contribute to innovative behavior and economic growth at the micro level. Similarly, other kinds of impact are difficult to measure, such as the extent to which increases in the pool of knowledge are a consequence of doctoral education.

Over the last two decades there has been a significant increase in studies tracing the career patterns of doctorate holders, in order to attempt to measure some of their potential impacts. More recently, these studies have focused on the mismatch problem referred to in the first section, expanding their scope to find out how doctorate holders are securing formal jobs, including mobility and migration aspects, but also how they are performing in their jobs: type of contract, earnings and involvement with teaching and research activities.

Institutional initiatives include the *Careers of Doctorate Holders* project, developed in 2004 by the OECD in partnership with UNESCO (OECD/UNESCO, Eurostat 2007; Auriol 2010; Auriol et al. 2012); the *Survey of Earned Doctorates* and *Survey of Doctorate Recipients* by the American National Science Foundation and the National Institutes of Health in conjunction with other federal agencies (Chang and Milan 2012; NSF 2013a, b); *Destinations of Leavers from Higher Education (DLHE)* and *DLHE Longitudinal Survey* (VITAE 2010); and the Graduate Destination Survey (GDS) (Graduate Careers 2013). Such studies are good examples of systematic efforts to map the incorporation of highly qualified human resources in labor market. They also offer methodological references for this kind of study in other countries [see, for instance, the Portuguese case in GPEARI/MCTES (2011)].

These studies show the concentration of doctorate holders' employment in the academic sector, albeit with an intensification of short-term contracts in recent years, including post-doctorate positions.[2] There is also an increasing trend in some countries (such as the USA) for PhDs to be employed in non-academic sectors, particularly those who graduated in the fields of engineering and sciences.

In addition, the majority of PhD holders have a relatively smooth transition to employment after graduation, engaging in some type of research career. It is also possible to find some mobility trends in terms of changes of jobs, regions and countries. Unemployment rates for PhDs are almost always relatively low, and premium wages for doctorate holders are common (Mangematin 2000; Enders 2002; Auriol et al. 2012; Neumann and Tan 2011; Cruz-Castro and Sanz-Menéndez 2005; Raddon and Sung 2009; Heitor et al. 2014; Zusman 2005; NSF 2013a, b;

[2] Post-doctorate (or post-doc) refers to a person who has taken a doctoral degree and spends some further time training in research before taking tenure-track jobs. In some countries like Brazil, it is also possible to get post-doc positions temporarily even after taking a permanent job position as a mean to improve some research skills or develop a new research field.

VITAE 2010). However, there are important differences among countries and knowledge fields (Basil and Basil 2006; Flynn et al. 2011; Innes and Feeney 2012; Lee et al. 2010; Kobayashi 2011; Luchilo 2010), and time period since graduation is also a factor.

Other studies have investigated more intangible aspects, such as personal motivations for PhD training (Mangematin 2000), expectations and preferences of PhDs about future employment based on the perceived rewards of different careers (Roach and Sauermann 2010; Gemme and Gingras 2012; Cruz-Castro and Sanz-Menéndez 2010), self satisfaction and perception of the importance of a PhD to professional trajectory (Enders 2002). From the labor market point of view, studies have examined the determinants of PhDs being hired in non-academic sectors (Garcia-Quevedo et al. 2012; Connor and Brown 2009), and how the skills and knowledge of advanced degree holders are used in different sectors (Lee et al. 2010; Auriol et al. 2012; OECD 2012a, b).

These studies have revealed some important findings about changes in the traditional reward systems of the academic and non-academic sectors. There has been some degree of cross-pollination between academia and industry, in terms of both sectors adopting practices typically associated with the other. For example, new pressures on funding in academia have led to increased commercialization and co-working with industry, while industry has adopted some elements of research environments, such as publications and research collaboration (Lee et al. 2010; Roach and Sauermann 2010). From the point of view of motivations and satisfaction, perceptions are quite diverse depending on the country, field of study and type of employment.

On the whole, these trends demonstrate the need to deal two problems: one quantitative, one qualitative. Firstly, the problem of the number of PhDs exceeding the number of appropriate job opportunities; and secondly, some degree of inadequacy of the skills developed when applied to non-academic employment. From the policy perspective, dealing with the quantitative problem may lead to attempts to restrict the number of PhD enrollments (Zusman 2005), although such a policy is not generally supported in the specialist literature, since a highly educated workforce (including PhDs) is acknowledged as a prerequisite for economic development and innovation.

Concerning the qualitative problem, the upshot is that new skills need to be developed in doctoral education, catering for those with a stronger or weaker “taste for science” [to use Roach and Sauermann’s (2010)] expression, and addressing the varied and changing needs of the PhD labor market in the higher education sector, industry, government and non-governmental organizations. In general, this means broadening the scope of doctoral education from formal knowledge in disciplinary fields to include other skills, more aligned with Mode 2 of knowledge production (Gibbons et al. 1994; Nowotny et al. 2001), as well as decreasing its traditional and limited self-reproductive function for the academic profession. Broadly speaking this suggests more diversity in organizational and structural forms of research training, in order to suit a multiplicity of careers (Enders 2002; Zusman 2005; Gemme and Gingras 2012; Halse and Mowbray 2011; Connor and Brown 2009).

There are a range of existing initiatives in this broad spectrum, including those aimed at supporting elite students to achieve academic positions, such as the NIH Oxford-Cambridge Scholars Program (McCook 2011); initiatives geared towards interdisciplinary research such as the National Science Foundation's Integrative Graduate Education and Research Traineeship Program—IGERT (Carney et al. 2006); and even university-industry collaborations such as the UK Engineering Doctorate (EngD) programs (Kitagawa 2013).

From the demand side, this situation imposes a request for initiatives that can help valuing PhDs in non-academic sectors, thereby widening employment opportunities. In the case of industry, this kind of initiative has well-established links to those that foster further private investment in R&D, which obviously only makes sense if there are economic incentives for innovation.

Besides the extensive set of R&D and innovation policies pursued by countries all over the world, it is interesting to highlight those policies particularly oriented towards increasing the number of doctorate holders employed in firms, such as the Spanish Program for the Employment of PhDs in Firms (*Acción para la Incorporación de Doctores en Empresas*—IDE) that subsidizes firms willing to contract junior PhDs not previously working in the company for R&D and innovation jobs [see Cruz-Castro and Sanz-Menéndez (2010) for an evaluation of this program].

Unfortunately, there seem to be few if any such formal initiatives to recruit doctorate holders into the government sector. This is regrettable, since research can and should play a major role in the policy-making process (Johnson and Williams 2011), and PhDs could make a valuable contribution to the government sector in this respect. Enders (2002) adds an important issue within the demand side debate, related to the need for a functional differentiation in the higher education sector, which could also support new possibilities for doctorate holders.

Increasing and even qualifying the offer of PhDs with more up-to-date and relevant skills without dealing beforehand with the demand for these professionals (as well as the conditions to benefit from the knowledge generated from their research), could even exacerbate the problem of supply-demand mismatch. In this way, incentives for R&D efforts in the private sector or for more effective links between research and the policy cycle and for valuing PhDs work in all sectors are essential.

Heitor et al. (2014) discuss the above argument in their presentation of employment indicators for PhDs awarded in Portugal over the period 1970–2008. They claim that the significant increase in the number of PhDs in Portugal in this period was accompanied by improvements in scientific and technological development, demonstrated by increases in scientific productivity and gross (total) business expenditure on R&D. The authors refer to this process as the "co-evolution of human capital formation and institutional research capacity building," since the incentives to PhD training were part of a synchronized set of public policies designed to foster R&D and innovation, and to promote the absorptive capacity needed by emerging regions and countries in order to learn how to use science for economic development.

This is also evident in the Chinese case, as presented by Ps et al. (2007) and Yang (2012). Despite only starting in the early 1980s, doctoral education has grown significantly in China in recent decades, becoming a significant part of the country's R&D and innovation efforts. In spite of some problems with quantitative and qualitative aspects of graduation studies in the country, it can be argued that as economic and market reform came before reform of the higher education system in China, economic prosperity created an increasing demand for PhD graduates.

The same may be said about South Korea, where the increase in the rate of PhD degrees was accompanied by equally elevated rates of GDP and industrial innovation (Marchelli 2005). The main lesson in these cases is the need of a balanced policy mix that complements and integrates initiatives to foster qualified doctoral education and economic development.

Whilst these are imperatives for the future of doctoral education, it is important to highlight [as Enders (2005) does] that PhD training is not just supposed to meet the demands of the labor market, but to push towards innovative activities and thus the creation of new demands not yet recognized by the labor market.

While some studies regarding doctorate holders in developing countries advocate increasing the number of PhDs as a means of generating social and economic development, there are also concerns about where to employ these skilled graduates outside the academic sector. There are neither large numbers of job vacancies that require a doctoral education, nor a significant premium wage associated with PhD degree [see for instance the Malaysian case in Ng et al. (2011), and the Indian case in Kumar et al. (2012)].

The assumption that countries should increase the number of PhDs as a means to generate social and economic development would seem to be a case of 'putting the cart before the horse', inasmuch as their governments first need to address the core problem underlying doctorate education—the demand issue. The mantra of the 'importance of skilled researchers' for bringing economic benefits—widely accepted for more developed countries—may be less clear cut for some less developed ones. To be clear, this does not mean that less developed countries should not aim to increase their highly skilled workforce. But given that these countries face a wide variety of problems, there is no single, cure-all solution.

Given the changing background of supply and demand of PhDs around the world, and the varying patterns of social and economic development of different countries, there is still much scope to explore the benefits of skilled graduates in various developing countries. The cases of China and Korea are probably more stereotypes than archetypes, for the situations among the so-called emerging countries can be very diverse. This gives rise to a number of questions. To what extent can such variables as type of employment, dedication to research, and earnings, be extrapolated from the studies about developed and some emerging countries (namely China and Korea)? And how far do public policies with respect to PhDs take into account the economic and social backgrounds of these less developed countries?

In respect of these questions, the Brazilian case is an interesting one to explore, since the country has also experienced a huge increase in the number of doctoral programs and doctorate holders in the last decade. Furthermore, it is also facing difficulties in generating the social and economic benefits of this doctoral education, because the supply-demand mismatch is also present, in particular due to the relative decrease in employment posts within the academic sector.

However, discussion about the actual and potential demand for these doctorate holders, and the new skills that need to be developed within the Brazilian economic context, is currently inadequate. This is due to the lack of systematic data gathering efforts in the country, such as surveys of doctorate holders' careers aimed at measuring both objective and subjective issues (employment positions and perceptions of doctoral graduates). Thus, comprehensive data and analysis of PhDs in Brazil is quite limited, despite the existence of two important (but not systematic) studies: Velloso (2004) and CGEE (2010).

14.3 Methods

The data and analysis presented in this manuscript are part of a more comprehensive research project evaluating scholarship programs of São Paulo Research Foundation (FAPESP), a Brazilian research agency that supports research in São Paulo State. The evaluation comprised the undergraduate research program, as well as master's and doctoral programs.

This manuscript is based on part of the data collected in this large study. It therefore deals mainly with data from doctorate holders who graduated in São Paulo State, which actually represents a significant share of doctorate holders who graduated in Brazil.

14.3.1 Data Collection

The data collection strategy used in the evaluation study consisted mainly of an online questionnaire completed by individuals who applied for one of the three scholarships programs offered by FAPESP in the period 1995–2009. This includes the group who were awarded scholarships as well as those who were rejected.

The questionnaire was quite extensive, but the items most pertinent to the present manuscript are information about doctoral education (location, period, and field of study), and information about their professional trajectory, including employment sector and region, salaries and dedication to teaching and research activities.

The questionnaire was pre-filled with information from each respondent’s Lattes Curriculum to facilitate completion and boost the response rate. The Lattes platform is a government-maintained open-data resource containing CVs and other information about researchers’ careers throughout Brazil, with a web interface used by virtually all researchers nationwide.

The questionnaire was posted on a specific website for 45 days in February and March 2012. Individuals were invited to complete the personalized questionnaire by email, using contact information available through FAPESP. A total of 57,490 emails were sent, of which 39,765 were successfully delivered.

14.3.2 Sample and Data Treatment

The response rate (based invitations successfully delivered) was 22 %, resulting in 8682 complete questionnaires.[3] From this total, 4134 questionnaires were answered by individuals who had completed their doctoral education. Thus, the study comprises data from PhDs who concluded their doctoral training in or before 2012 and applied for one or more of the FAPESP scholarship programs between 1995 and 2009, regardless of whether this was awarded or not. It should be highlighted that are some missing values for some of the variables analyzed: this is why the sample size varies in the ‘Findings and Discussion’ section.

It is important to note that the evaluation study was not conceived as an exhaustive analysis of the professional trajectory of doctorate holders in Brazil. Notwithstanding, it collected a detailed and meaningful quantity of data on variables that provide valuable information about the Brazilian case.

Two additional comments are worth mentioning, in order to better understand the sample and the corresponding data used in this manuscript. Firstly, São Paulo State—one of the 27 Brazilian States—produces almost 50 % of graduated PhDs in Brazil. This State is also home to 21.7 % of the Brazilian population, and provides circa 33 % of its Gross Domestic Product and more than 50 % of its scientific production. Secondly, FAPESP has a strong reputation among the national scientific community, particularly due to its rigorous peer review system. This means that those who normally apply to FAPESP have high academic standards and research potential. Thus, data gathered from this group sheds light on issues not yet discussed in the literature, contributing to a broader understanding of the Brazilian case and its differences from other countries.

As already expected considering the study design, the vast majority of doctorate holders from the sample (97.5 %) completed their doctoral studies in São Paulo State, with 1.8 % in other countries and 0.6 % in other States of the country.

In order to answer the main research questions of the manuscript, the collected data about doctorate holders was analyzed in respect of their professional trajectory,

[3] By ‘complete responses’ is understood questionnaires with all required information about undergraduate and graduate education.

including labor market aspects (employment sector, region and dedication to teaching) and research activities and market value of PhDs (wages and premiums). The analysis was compared to general trends from similar studies of other countries, and also to a previous study about PhDs in Brazil (CGEE 2010) regarded as the main source of data of this kind in the country.

Although it is possible to draw general conclusions from the aggregated data, it is important to distinguish between behaviors among distinct fields of study and time period since graduation. As discussed above, the existing literature shows relevant differences considering these variables.

The distribution of the sample according to the main field of study of doctorate holders is shown in Fig. 14.1, in terms of both the number of PhDs and the accumulated share in the sample.

In addition, the distribution of the sample considering time since graduation is presented in Table 14.1.

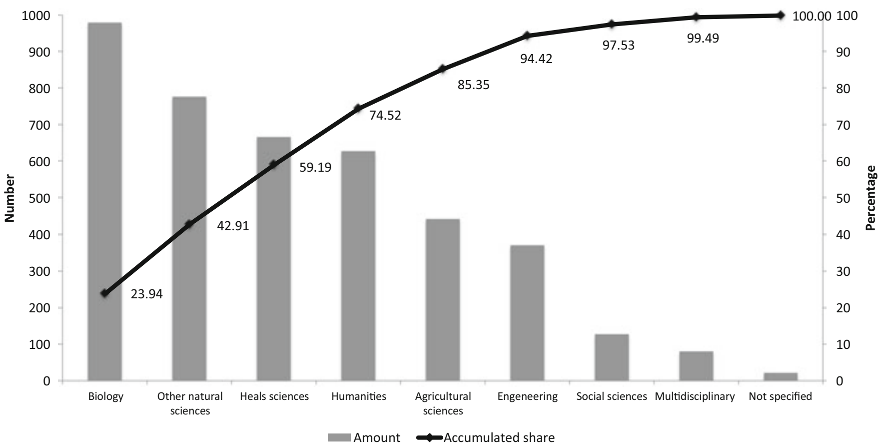

Fig. 14.1 Distribution of the sample by knowledge fields (number and %)

Table 14.1 Distribution of the sample by time period since doctorate completion (number and %)

	Time interval	Amount	Percentage
Doctorate holders with *more than 10 years* since graduation	<2003	494	14
Doctorate holders with *more than 5 and less than 10 years* since graduation	2003–2007	1,470	41
Early career doctorate holders (*less than 5 years* since graduation)	>2007	1,636	45
		3,600	100

14.4 Findings and Discussion

14.4.1 Labor Market

More than 52 % of doctorate holders from the sample declared they did not have formal jobs in 2012. 37.1 % of the whole sample declared holding some sort of post-doctoral position. It is worth noting that a post-doc position in Brazil may or may not include pecuniary earnings (scholarships or other types of payments), but it is never classified as a formal job.

This finding reveals an important concern regarding the mismatch between the supply and demand of highly qualified human resources in the country, since the Brazilian unemployment rate in 2012 was 5.5 %,[4] almost one tenth of the rate found for doctoral graduates (including those that declared being in post-doc activities). The unemployment rate for greater São Paulo in the same year was practically the same (5.2 %).

A study by CGEE (2010) which gathered data from doctorate holders who finished their PhDs between 1996 and 2006 showed an unemployment rate of almost 30 % (the data gathering took place in 2008). The difference between the two studies is probably due to the different samples (the CGEE study dealt with nationwide data while ours was for Sao Paulo's State alone), and different periods covered (ours goes up to 2012, i.e. 4 years longer than the CGEE one, a period in which the number of PhDs increased by more than 18 % in the country). From any perspective, the rates of unemployment in both studies are far higher than in found in other countries.

Many studies have shown an unemployment rate of around 1 % for doctorate holders in other countries. Auriol et al. (2012) in a study covering 20 countries including both developed and less developed countries found an average rate of 1.2 %. The American survey of earned doctorates (NSF 2013a) showed an unemployment rate of about 2 % in 2010. Even considering the more recent studies showing an increasing mismatch between supply and demand of doctorate holders (Taylor 2011; Cyranoski et al. 2011; Neumann and Tan 2011), the figures are far lower than those found in the Brazilian case. One does not find a phenomenon of 30 % or more unemployment, suggesting a problem that needs to be analyzed and tackled.

Furthermore, in spite of being one of the main tracks followed by PhDs around the world, the elevated rate of post-doctoral positions in the sample reinforces this mismatch. In Brazil, post-doc does not denote a particular kind of job contract with host institutions, as is typically the case in many countries. It is just a temporary connection, which can help in the securing of tenure-track professor jobs, but by no means guarantees them.

More than 70 % of those individuals in the sample that held post-doctoral positions in 2012 gave as their main motivation the opportunity to continue developing research activities. Hence, a post-doc can be seen as a provisional solution that a great number of PhDs turn to while waiting for a research job opportunity to arise.

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[4] Information from monthly Employment Survey (PME) from Brazilian Institute of Geography and Statistics (IBGE).

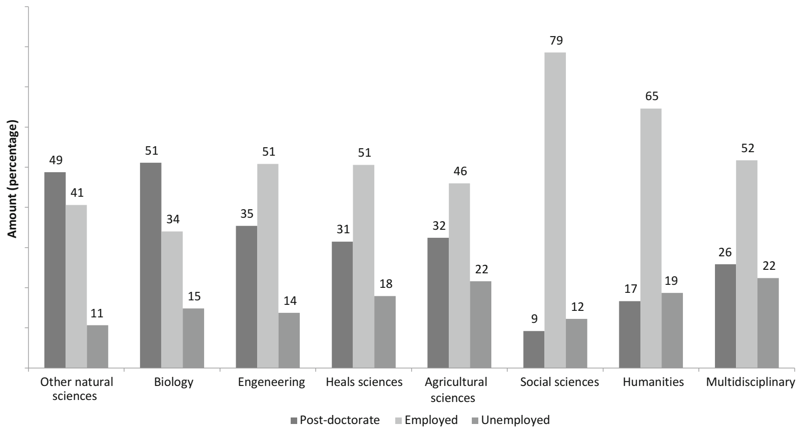

Fig. 14.2 Employment status among knowledge fields

Variations in the employment status of doctorate holders across fields of study (Fig. 14.2) indicate different situations. Sciences (physics, chemistry, mathematics and earth sciences) and Biology fields have similar profiles, in that post-docs are quite common (about 50 % of PhDs from the sample in these fields in 2012). A post-doc is considered a particularly important prerequisite in these fields for achieving permanent academic positions, and it is a "natural" path for those who have not obtained a job position and want to pursuit academic activity.

Engineering, health sciences, agricultural sciences, and multidisciplinary fields are similar to each other in terms of formal unemployment rates. Social sciences and humanities comprise another group, inasmuch as post-doctoral positions are not common (half or less of the sample's average), and employment rates are higher (almost 80 % in social sciences). This is in accordance with Brazilian data from 2008 (CGEE 2010).

Employed PhDs from the sample were mostly working in six economic sectors in 2012[5]: educational services (68.6 %), professional, scientific and technical services, which comprises R&D and consultancy (12.4 %), health care and social services (5 %), agriculture (3.8 %), public administration (1.3 %), and manufacturing (1.1 %).

Previous findings from CGEE (2010) on the general employment situation of Brazilian PhDs are similar to our own. In 2008, the most important employers for PhDs who graduated since 1996 were educational services (76.8 %), public administration (11.1 %), professional, scientific and technical services (3.8 %), health care and social services (3 %) and manufacturing (1.4 %). The difference in the share of public administration between data presented here and the one from CGEE (2010) is due to the large number of PhDs with jobs in federal public administration that

[5] This classification is based on the National Classification of Economic Activities (CNAE) of the Brazilian Institute of Geography and Statistics (IBGE).

Table 14.2 Share of PhD employment across economic sectors, by time period since doctorate completion

	<2003	2003–2007	>2007	Trend test p-value[a]
Educational services	69.6	70.0	66.7	0.082
Professional, scientific and technical services	13.9	12.1	11.7	0.218
Health care and social assistance	2.6	4.7	7.3	<0.001
Agriculture	4.4	4.5	3.2	0.077
Manufacturing	0.4	1.1	1.4	0.092
Public administration	1.5	1.5	1.4	0.971

[a]Linear tests performed by logistic regression models

are located mainly in Brazil's central region and also Rio de Janeiro State (and not in São Paulo State).

A comparison of those who graduated in 1996 with those who graduated in 2006 within the same study (CGEE 2010) also shows that the education sector has been losing ground as an employment destination. The same conclusion can be drawn when comparing the CGEE study with our own, since the education sector's share decreased when analyzing the sample by time period since doctorate completion. This trend—associated with the increase in some other sectors—is shown in Table 14.2.

In the case of the manufacturing sector, it is worth noticing that while the overall share is modest, the increase is significant over time.

In terms of the prevalence of doctorate holders' jobs in the academic sector and the recent increase of other sectors' share, these results also accord with worldwide patterns found in the existing literature. Nevertheless, data from the sample indicates that the share of PhD employment in the manufacturing sector is about 14 times less than the share of doctorate holders' employment in business enterprises in other countries (Auriol et al. 2012). In addition, very few employed PhDs declared themselves as entrepreneurs (2.8 %), reinforcing the previous evidence.

The evidence presented here suggests that the impacts of PhDs in Brazil are mainly in teaching and learning effects related to academic jobs. There are minimal impacts on creating a generation of new or improved products processes and services in the country, or the generation of R&D environments within the firms. Although it is possible to argue that knowledge developed in universities or research organizations by this critical mass of PhDs could be transferred to industry and/or the services sector, it is well known that some absorptive capacity is needed to effectively use this knowledge in order to foster innovation.

What aggregate data from Brazil shows is that the development of this absorptive capacity towards innovation is very much limited. According to OECD (2012a, b), Brazilian business R&D expenditure was in the middle range below the OECD median in 2011. The Brazilian innovation survey (IBGE 2013) supplements this finding, since 36 % of firms declared some kind of technological innovation in the period 2009–2011, but less than 10 % these developed products or processes new to the country. About 5 % of those firms had some kind of internal R&D efforts; the average R&D expenditure was less than 1 % of net sales revenues and about 10 % of individuals working in R&D activities had some kind of post-graduate degree (master's or PhD). In addition, the low shares of PhDs in other sectors such as health care and public administration reinforce the general argument of weak demand for highly qualified researchers in the country.

The relationships between field of study and sector of employment also show some interesting although perhaps expected results. 76 % of those working in the agriculture sector graduated in agricultural related disciplines; 75 % of those working in manufacturing graduated in sciences and engineering; 92 % of those working in health care and social services graduated in biology and health sciences. PhDs who graduated in social sciences are poorly involved in professional, scientific and technical services, and even in the educational services sector.

Most of the employed PhDs declared involvement in both teaching and research activities (46.6 %), just research (19.6 %) or just teaching (9.3 %), which means that almost 75 % of these highly qualified human resources are utilizing 'traditional' PhD skills in their jobs. Furthermore, a significant share of PhDs were working in public institutions (63.6 %).

Table 14.3 correlates the most represented economic sectors with the type of activities pursued by doctorate holders.

The previously described results along with those in Table 14.3 show other important and complementary features that help to understand the professional careers of doctoral graduates in the country. In the Brazilian educational services sector, there is a historical divide between public universities, seen as centres of excellence for both teaching and research, and the private ones, which despite accounting for around 70 % of undergraduate enrolments generally do not perform

Table 14.3 Economic sectors and dedication to teaching and research (number and percentage)

	Teaching and research	Research	Teaching	Not dedicated to teaching and research	Total
Educational services	461	22	85	27	595
	77 %	4 %	14 %	5 %	100 %
Professional, scientific and technical services	34	51	4	23	112
	30 %	45 %	4 %	21 %	100 %
Health care and social assistance	25	14	3	42	84
	30 %	17 %	3 %	50 %	100 %
Agriculture	0	33	1	5	39
	0 %	85 %	2 %	13 %	100 %
Public administration	4	2	1	10	17
	23 %	12 %	6 %	59 %	100 %
Manufacturing	0	13	1	5	19
	0 %	69 %	5 %	26 %	100 %

research, having relatively few graduate programs and quite a restricted number of employed PhDs (Balbachevsky 2004).

Moreover, careers in public higher education institutions are guided by very structured careers plans: faculties are selected and hired by public tender; they are generally supposed to have full-time contracts and to perform teaching, research and 'third mission' activities simultaneously; space in institutions for researchers (not involved in teaching) are very restricted. On the other hand, private higher education institutions have much more freedom to establish part-time contracts and to hire professionals solely for teaching, without any stimulus or support for them to perform research activities.

Another Brazilian feature is the important role of public research organizations in graduate education, since quite a significant number of these institutions also provide master's and doctoral education in their fields of expertise. As can be seen, almost 30 % of doctorate holders in professional, scientific and technical services (which is mainly constituted by public research organizations) also dedicate themselves to teaching along with their research activities.

In health care and social services, and also public administration, doctorate holders are mostly not involved in teaching and research, which could indicate some diversification of the traditional PhD skills into non-academic sectors. Nevertheless, the most probable explanation is that a large number of posts in these areas are obtained by public tender, which traditionally values a doctoral degree as a criterion for general classification of candidates, but does not necessarily make use of doctoral skills in everyday activities. In addition, it is worth noting that public administration also values the doctoral degree as a means of professional advancement and related rewards.

Although also limited by the number of observations, the agriculture sector can be distinguished in terms of research, which accords with the importance of the sector in the Brazilian export market. In the manufacturing sector, although low in total and relative numbers, PhDs are mostly involved in R&D activities.

The underlying conclusion is that PhD skills are most obviously valued in jobs that requires teaching and research activities. Doctoral education to a large extent thus fulfils a self-reproductive function for the academic profession. PhDs are somewhat undervalued in other sectors, perhaps as a result of demand-supply mismatch, or more probably because there is little demand for PhDs with either traditional or new and diversified skills in the country.

The other important feature of the Brazilian PhD labor market is the aforementioned regional research concentration in the country. The majority of PhDs from the sample were working in São Paulo State (69.4 %) in 2012, which was expected given that they completed their doctoral training there. Considering that 97.5 % graduated in the State, a 28 % rate of migration can be derived. Data from CGEE (2010) suggested a similar trend, with 22 % of those who graduated in São Paulo between 1996 and 2006 working in other regions of the country in 2008. São Paulo was and still is the main research and economic center of Brazil, although it has been recently losing ground to other regions of the country. This is also a matter of policy importance, since regional decentralization can certainly contribute to boosting demand for PhDs within the country.

14.4.2 Market Value

About 50 % of doctorate holders from the sample had in 2012 a wage of nine to fifteen times the national minimal wage, which corresponded approximately to US$ 2,800 to US$ 4,800 per month (Fig. 14.3). The average monthly earnings of the employed PhDs in 2012 was US$ 3,700. Previous data from CGEE (2010) gave an average amount of US$ 4,444 in 2008 of those graduated from 1996 to 2006,[6] which can either suggest some loss between 2008 and 2012 or just an ad hoc result of different samples and time periods as mentioned above.

As predicted, there is some variation when considering time period since doctorate completion (Fig. 14.4). Around 41 % of those with more than 10 years since graduation earned over US$ 4,785 per month, while for those with 5–10 years since graduation the percentage is 22, and 16 % for early-careers. However the difference among the curves is not so marked, which means that PhD wage progression in Brazil is quite restricted. A feasible explanation for this is that the majority of doctoral graduates' jobs are in public higher education and research institutions, where wages vary in accordance with an established career plan. The pay scales are adjusted from time to time, with no space for negotiation for higher skills or even outstanding performance, although there are pecuniary compensations related to service time and administrative positions. Considering,

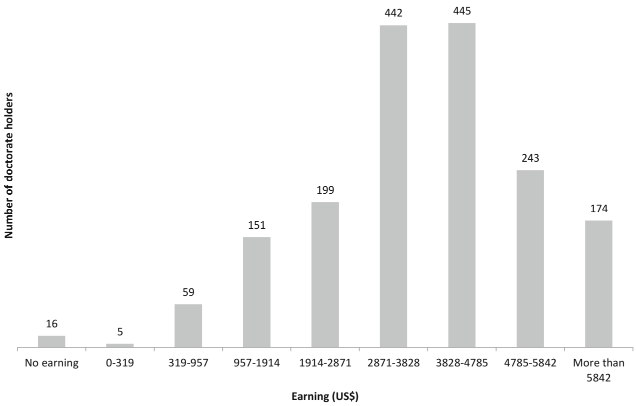

Fig. 14.3 Distribution of doctorate holders' earnings in 2012

[6] Conversions made using rates from 2012 (US$1 = R$1.95) and National Broad Consumer Price Index (IPCA) to update values.

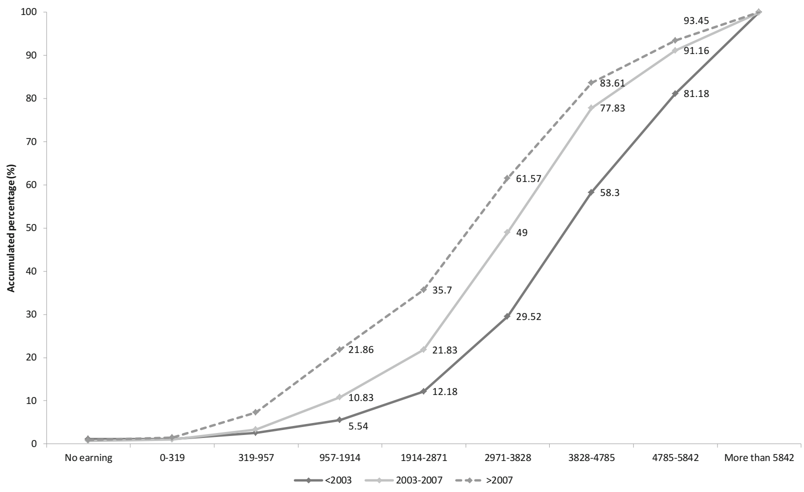

Fig. 14.4 Accumulated doctorate holders’ earnings in 2012 (US$1 = R$1.95) by time period since doctorate completion

for instance, a faculty career in Brazilian federal higher education institutions in 2012, the difference between the first level (equivalent to a lecturer) and the last level (equivalent to professor) was just 38 % (not considering the additional pecuniary compensations mentioned above). In São Paulo higher education institutions, for the same year, the difference was even less—about 30 % (again, not considering the additional pecuniary compensations).

There were no significant differences in PhD earnings between different fields of study, according to the 2012 data. For sciences, engineering and social sciences, wages are 10 %, 13 % and 11 % higher than average respectively. For other fields, they are lower than average, in particular for biology (9 % less). Similar results were found in CGEE (2010), with engineering and social sciences graduates earning 8 % and 30 % more respectively.

The average wage a Brazilian employee with higher education in 2012 was US$ 2,265, which equates to a PhD wage premium of around 64 %.[7] This is a very elevated rate compared with data from USA and UK in 2003–2011—almost 35 % in the first case and 15 % in the second (OECD 2013). When compared to the national average wage of employees with no higher education, the premium for a PhD graduate rises to 428 %.[8]

Figure 14.5 depicts the variation in the PhD wage premium among different economic sectors in Brazil. It is quite important to note that while in public administration and educational services the pecuniary returns from the possession

[7] Data from Central Register of Enterprises—IBGE.

[8] Ibdem.

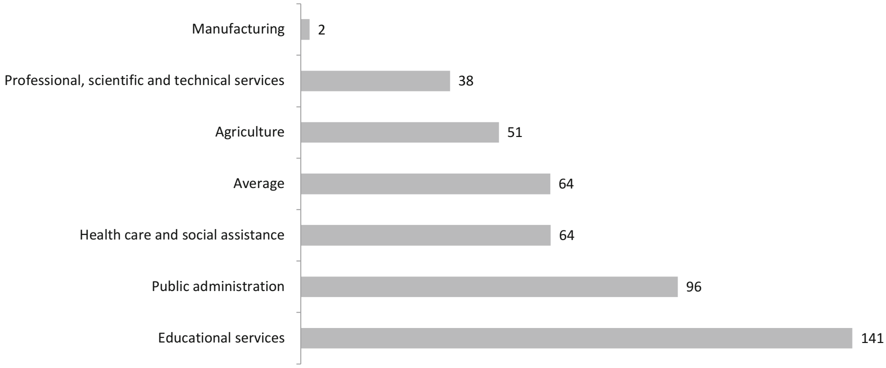

Fig 14.5 PhD wage premium among economic sectors, in relation to employees with higher education

of a PhD are higher than average in the country, in other significant sectors such as manufacturing the premium can be very low if not insignificant.

The most noteworthy finding is the "ineffectiveness" (from the individual's point of view) of holding a doctoral degree in industrial employment. This can be explained by the low rates of investment in R&D activities by companies, but also by the fact that the research performed in industry does not require PhDs (although it often requires further technical—and commonly management—training of their graduate employees). This raises an important question about the demand-supply mismatch, which is not only large in general, but particularly so in the industrial sector.

On the other hand, in several other sectors the possession of a PhD qualification in Brazil brings a significant premium. In addition, wage increases along PhDs' career paths are very limited, which has much to do with the features of faculty careers in public higher education institutions in the country, but also with the valuation problem of doctoral graduates' skills discussed above.

14.5 Conclusion

To return to the initial questions set at the start of this chapter, it is possible to conclude that doctorate holders in Brazil are not being adequately absorbed by the labor market, which imposes important constraints in terms of generating economic and social impacts.

In summary, comparing the results presented in the previous sections to similar studies of developed countries, one can find analogous results: disequilibrium between PhDs' supply and demand; prevalence of doctorate holders' employment in higher education (although with a decreasing trend in recent years); emergence of employment of doctorate holders in other sectors; PhD premium wages and variances among fields of study and time period since PhD completion. Nevertheless, the imbalances are much more evident in the Brazilian situation. The supply-demand mismatch is much higher than in other countries, while the share of PhD employment in non-academic sectors is still much lower, particularly in the manufacturing sector. Premium wages are reasonable in Brazil, but overall earnings are still below expected considering the qualifications of doctorate holders, and they increase relatively little over the course of an individual’s career.

What does this means in terms of impact of PhD holders in the country? On the one hand, Brazil has achieved great success in improving its doctoral programs and creating new PhDs at an unprecedented rate. This had obviously increased the ‘pool of knowledge’ in the country, a fact reinforced by recent achievements from Brazilian scientific production. Analysis of the Scopus database indicates that the scientific production of the country increased 3.5 times from 2001 to 2011, resulting in Brazil moving up to 13th place for quantity and 17th place for citations. In the same year, for scientific production indexed by Web of Science, Brazil held the 15th and 20th positions respectively. This is quite a good performance and has much to do with supporting research of PhD holders, but also fostering international collaborations and the quality of doctoral programs based on the quality of faculties and students’ publications.

The teaching and learning effects of doctoral education can also be estimated, although it is difficult to find objective measures for doing so. The large number of PhDs absorbed by higher education and research organizations actually involved with teaching (both in undergraduate and graduate programs) is in itself evidence of this kind of effect. Private returns can also be addressed as recognizable impacts, since wage premiums associated with having doctoral degrees are huge in the country.

In terms of creating innovative environments and fostering innovation in the country, impacts are very limited, which means that doctoral education in Brazil is being utilized much more by the academic profession than for other activities. While to some extent this may be the result of the lack of industry-oriented skills of PhDs, the main reason is the innovative profile of Brazilian firms. R&D efforts are limited, and most innovations that do take place are only “innovative” at the level of the firm; few are new to Brazil, and even less are new to the world as a whole.

The main implication of this analysis is the necessity of promoting a more convergent path between doctoral education policies and research and innovation policies. In spite of being a common characteristic among many countries, the unbalance between PhD supply and demand is perhaps much more evident in emerging countries like Brazil, precisely because the gap between the creation of research capabilities and the creation of research-based job positions in non-academic sectors is wider than in developed economies.

In the Brazilian case—as is the case in many less developed countries—this sort of unbalance might also be the result of a historical trajectory where policies for training high level students were much more effective than policies designed to absorb these trained personnel by fostering innovation and/or adequate links between public policy formulation and evaluation and research.

Brazil is not a case of a country that has overdeveloped its academic sector, but rather a country that has not developed an STI system in a more balanced way. The same country that today is producing almost 3 % of the total scientific publications in the Web of Science is filing less than 0.1 % of patents in the USPTO. Even considering these are quite narrow indicators, they do reveal characteristics from the Brazilian system of science, technology and innovation that are wholly consistent with the results presented in this chapter.

This does not mean that investments in PhDs programs should be cut to equalize the situation. Nor should new job positions specifically for PhDs be artificially created if their competences will not be used effectively in daily tasks. To reduce the strong imbalance evident in Brazil and in other less developed countries is a matter of rethinking the whole STI system and starting to stimulate true demand for high-qualified individuals.

In this perspective, one important recommendation for the near future would be the promotion of convergence among policies in a way that allows them to co-evolve in terms of their synergic and integrated effect. As pointed out by Flanagan et al. (2011) there is a clear trend in many countries towards the promotion of a mix of policies. When a policy mix is developed as part of a coherent strategy, economies of scale and scope are more likely to emerge than when these policies are not designed and implemented in an integrated way.

Given the evidence presented here about the Brazilian case, it is not enough to rethink doctoral education in terms of approaches and skills. It is necessary to act on the demand side, which means developing and implementing effective innovation policies, but also changing the actual parameters of public sector careers, mainly in higher education and research organizations, including functional differentiation and hiring flexibility parameters. In addition, considering the particularities of the Brazilian case, there are two complementary policies that have to be added to the policy mix in order to promote the real co-evolution of human capital formation and institutional research capacity building. These are research decentralization in the country, which is already a target of public policies in Brazil, and the quality of private higher education institutions, which was a priority in the past but not at present. Only an effective policy mix could support new possibilities for doctorate holders in the country, since the Brazilian problem is not so much the lack of skills constraining economic growth, but rather the lack of incentives and effective ways to use these skills.

Although the use of regional concentrated data could be considered a limitation in this study, the sampling of PhDs who graduated in São Paulo State and applied for scholarships in FAPESP means that the sample comprises part of the elite of PhDs in Brazil. Of course, other particularities could be found in a more comprehensive sample of Brazilian PhDs, but the overall conclusions would be nearly the same, as shown by the evidence of CGEE (2010).

Finally, despite the evidence presented here about the supply-demand mismatch of PhDs in Brazil, further investigation is still needed on this subject. Implementing systematic studies to map doctoral graduates' careers in Brazil and also expanding investigations into the incentives in different economic sectors for hiring PhDs would seem to be a first step in this direction.

References

Auriol L (2010) Careers of doctorate holders: employment and mobility patterns. In: OECD Science, Technology and Industry working papers 2010/04. OECD Publishing, Paris. doi: 10.1787/5kmh8phxvvf5-en

Auriol L, Misu M, Freeman R (2012) Doctoral graduates in times of economic downturn: labour market participation and mobility. Working party of national experts on science and technology indicators. Directorate for Science, Technology and Industry—Committee for Scientific and Technological Policy. OECD Publishing, Paris

Balbachevsky E (2004) Graduate education: emerging challenges to a successful policy. In: Brock C, Schwartzman S (eds) The challenges of education in Brazil. Oxford studies in comparative education. Triangle Journals Ltd, Oxford, pp 209–228

Basil MD, Basil DZ (2006) The marketing market: a study of PhD supply, demand, hiring institutions, and job candidates. J Bus Res 59:516–523

Carney J, Chawla D, Wiley A, Young D (2006) Evaluation of the initial impacts of the National Science Foundation's integrative graduate education and research traineeship program. Final report

Casey BH (2009) The economic contribution of PhDs. J High Educ Policy Manag 31(3):219–227

CGEE (2010) Doutores 2010: estudos da demografia da base técnico-científica brasileira. Centro de Gestão e Estudos Estratégicos, Brasília, DF

Chang W, Milan LM (2012) International mobility and employment characteristics among recent recipients of US doctorates. Infobrief—NCSES. NSF 13-300

Cohen WM, Levinthal DA (1989) Innovation and learning: the two faces of R&D. Econ J 99 (397):569–596

Connor H, Brown R (2009) The value of graduates and postgraduates. Council for Industry and Higher Education, London

Cruz-Castro L, Sanz-Menéndez L (2005) The employment of PhDs in firms: trajectories, mobility and innovation. Res Eval 14(1):57–69

Cruz-Castro L, Sanz-Menéndez L (2010) Mobility versus job stability: assessing tenure and productivity outcomes. Res Policy 39:27–38

Cyranoski D, Gilbert N, Ledford H, Nayar A, Yahia M (2011) The PhD factory: the world is producing more PhDs than ever before. Is it time to stop? Nature 472(21):276–279

Gabinete de Planeamento, Estratégia, Avaliação E Relações Internacionais (Gpeari)/Ministerio da Ciencia, Tecnologia e Ensino Superior (2011). Fluxos e situacão profissional dos doutorados em Portugal—2009

Enders J (2002) Serving many masters: the PhD on the labour market, the everlasting need of inequality, and the premature death of Humboldt. High Educ 44:493–517

Enders J (2005) Border crossings: research training, knowledge dissemination and the transformation of academic work. High Educ 49:119–133

Flanagan K, Uyarra E, Laranja M (2011) Reconceptualising the 'policy mix' for innovation. Res Policy 40:702–713

Flynn CB, Field HS, Bedeian AG (2011) "Life could be a dream": what US-based management PhD students desire in an initial academic appointment. Career Dev Int 16(4):316–341

Garcia-Quevedo J, Mas-Verdú F, Polo-Otero J (2012) Which firms want PhDs? An analysis of the determinants of the demand. High Educ 63:607–620

Gemme B, Gingras Y (2012) Academic careers for graduate students: a strong attractor in a changed environment. High Educ 63:667–683

Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M (1994) The new production of knowledge: the dynamics of science and research in contemporary societies. Sage, London
Graduate Careers Australia (2013) Australian graduate survey 2012: a report of the conduct of the 2012. Australian Graduate Survey
Halse C, Mowbray S (2011) The impact of the doctorate. Stud High Educ 36(5):513–525
Heitor M, Horta H, Mendonça J (2014) Developing human capital and research capacity: science policies promoting brain gain. Technol Forecast Soc Chang 82:6–22
IBGE (2013) Pesquisa de Inovação Tecnológica 2011. IBGE, Rio de Janeiro
Innes P, Feeney D (2012) Career paths of AHRC funded PhD students. Final report
Johnson S, Williams G (2011) Evaluating the impact of social scientists. Final report to Economic and Social Research Council, UK
Kitagawa F (2013) How to capture the impact of the Engineering Doctorate (EngD) programme to industry?—conceptual and methodological issues related to measuring the performance of the Triple Helix approach. Triple Helix international conference XI, 8–10 Jul, London
Kobayashi S (2011) The PhD as a professional: current status and issues concerning the early careers of doctorate holders. Jpn Labor Rev 8(4):46–66
Kumar V, Kumar N, Sapnanarula S (2012) Plethora of Indian education: are we following the development path? Liceo J High Educ Res 7(1):39–46
Lee H, Miozzo M, Laredo P (2010) Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university. Res Policy 39:869–881
Leitch S (2006) Prosperity for all in the global economy—world class skills. Final report. HMSO, London
Luchilo L (2010) Formación de posgrado en América Latina: políticas de apoyo resultados e impactos, 1ath edn. Eudeba, Buenos Aires
Mangematin V (2000) PhD job market: professional trajectories and incentives during the PhD. Res Policy 29:741–756
Marchelli PS (2005) Formacão de doutores no Brasil e no mundo: algumas comparacões. RBPG 2 (3):7–29
McCook A (2011) Rethinking PhDs. Nature 472:280–281
Neumann R, Tan KK (2011) From PhD to initial employment: the doctorate in a knowledge economy. Stud High Educ 36(5):601–614
Ng SF, Muhd NMN, Rahman KA, Ismail N (2011) Influential factors to pursue doctorate degree in Malaysia. Procedia Soc Behav Sci 15:2028–2032
Nowotny H, Scott P, Gibbons M (2001) Rethinking science: knowledge in an age of uncertainty. Polity Press, Cambridge
NSF (2013a) Survey of Doctorate Recipients—SDR. Available at http://www.nsf.gov/statistics/srvydoctorates/
NSF (2013b) Survey of Earned Doctorates—SED. Available at http://www.nsf.gov/statistics/srvydoctoratework/
OECD (2012a) Transferable skills training for researchers: supporting career development and research. OECD Publishing, Paris
OECD (2012b) OECD Science, Technology and Industry outlook 2011. OECD Publishing, Paris
OECD (2013) Key findings of the OECD-Knowinno project on the careers of doctorate holders. OECD Publishing, Paris
Organisation for Economic Co-operation and Development (OECD)/UNESCO, Eurostat (2007) Mapping careers and mobility of doctorate holders: draft guidelines, model questionnaire and indicators: the OCDE/UNESCO Institute for Statistics Eurostat Careers of Doctorate Holders (CDH) Project, OECD Science, Technology and Industry working paper, 2007/6. OECD Publishing, Paris
Pavitt K (1991) What makes basic research economic useful? Res Policy 20:109–119
Ps L, Li L, Zong L (2007) Postgraduate educational aspirations and policy implications: a case study of university students in western China. J High Educ Policy Manag 29(2):143–158

Raddon A, Sung J (2009) The career choices and impact of PhD graduates in the UK: a synthesis review. ESRC, RCUK, Leicester
Roach M, Sauermann H (2010) A taste for science? PhD scientists’ academic orientation and self-selection into research careers in industry. Res Policy 39:422–434
Salter AJ, Martin BR (2001) The economic benefits of publicly funded basic research: a critical review. Res Policy 30:509–532
Taylor M (2011) Reform the PhD system or close it down. Nature 472:261
Tremblay K (2005) Academic mobility and immigration. J Stud Int Educ 9(3):196–228
Velloso J (2004) Mestres e Doutores no País: destinos profissionais e políticas de pós-graduação. Cad Pesqui 34(123):583–611
VITAE (2010) What do researchers do? Doctoral graduate destinations and impact three years on 2010. The Careers Research and Advisory Centre, RCUK, Cambridge
Yang R (2012) Up and coming? Doctoral education in China. Aust Univ Rev 54(1):64–71
Zusman A (2005) Challenges facing higher education in the twenty-first century. In: Altbach PG, Berdahl RO, Gumport PJ (eds) American higher education in the twenty-first century: social, political, and economic challenges, 2nd edn. The Johns Hopkins University Press, Baltimore

Part IV

Conclusion

The Meaning of Doctorate Holders for Human Capital Development of Nations 15

Dirk Meissner, Leonid Gokhberg, and Natalia Shmatko

Given the constantly high demand for skilled workers in professions and industries around the world, national governments strive for developing and implementing comprehensive and sustained policy measures to develop human potential of countries. This is especially done by educating people towards tertiary graduates and most recently by enforcing doctoral education and training. The aim of these initiatives is to make highly qualified graduates available to the labor market with the ambition to achieve and maintain sustainable competitiveness of the national labor force (OECD 2011). There is consensus that if countries want to develop and maintain competencies and capacities for science, technology and innovation the education and training system needs to be strengthened at all its levels.

So far countries often focused initially on primary and secondary education but did not touch upon all facets of tertiary education. Initiatives to strengthen tertiary education were frequently targeted at undergraduate and graduate education while postgraduate programs were hardly in the focus of policy initiatives. This has changed considerably in the last decades especially in European countries (OECD 2012; Powell 2013). However in many countries the number of doctorates graduating successfully from doctoral programs has risen stronger than expected while actual demand has remained at almost similar level. This poses new challenges on doctoral students themselves but also on higher education institutions and on education and labor policy makers (OECD and World Bank 2007). In scientific, political and increasingly public debates the question arises how many doctorates society, science and industry need to be equipped for meeting current and future challenges. From an economic point of view this concern is plausible but it neglects a number of issues:

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- Despite attempts to redirect doctoral education and training it still remains targeted in the first instance towards scientific progress and achievements which are typically showing impact in the long run rather than short term effects. Therefore the expectations of immediate outputs from such activities may become counterproductive.
- The contribution of individual doctorates to scientific progress is in most cases unclear at the time the doctoral work is made. Initial assessments of these efforts by experienced and established scientists usually take account of the newness of results and the quality of the approach chosen to achieve the objectives. This implies that the novelty of the findings contributes to the extension of the knowledge base but not necessarily shows direct relation and reference to technological and innovation development.
- Nevertheless, the common assumption is that doctoral thesis as the major output from doctoral studies contributes to technology and innovation advances. However the assessment standards for these works are not explicitly considering such contributions of doctoral research. Instead, as mentioned above, the latter is assessed regarding the newness of the topic and the findings of this work for science. Also the evaluators of these works are typically strongly involved in the science community and familiar with the state of the art in scientific terms which allows them a respective judgment. But these assessments are in the minority of cases only relevant for technology and innovation mainly because the evaluators may lack the necessary in-depth knowledge and awareness of these. Accordingly the assumption that doctoral research itself contributes to technology and innovation is at least partially misleading.
- The major contribution from doctorates to technology and innovation development comes from the overall set of competencies doctoral students acquire during the education and training process. While the subject-field knowledge is doubtless the most important element, other knowledge and proficiencies are also valuable. These include competencies of structured work as well as analysis and synthesis of complex problems. It is often forgotten that even the competency of detecting and describing problems is the one which is of crucial importance for the qualified labor force.
- Doctoral research targets at developing new algorithms and approaches towards problem and challenge solution. Typically these results, e.g. approaches are not fully applicable and compatible with existing and/or emerging technologies. Therefore in light of strengthening the national technology and innovation competency base the short term view on doctorate graduates is not completely rational, instead they should be considered as human capital investment in future technological and innovation solutions with forward-looking application potential.

These arguments imply that there is an urgent need for a more targeted thinking of the role and meaning of doctorate holders in national innovation systems (NIS)' competencies and capabilities schemes. First, there are doctorate holders who have demonstrated their skills of structured work for problem detection and solving in course of their doctoral education and training. This group of doctorates makes an important contribution to the overall qualification level of the labor force in a country. Second, there is a cohort of recent doctorate graduates who have shown competencies in scientific activities. Presumably such capabilities are one important element of future work and potential achievements of these doctoral graduates. However development of doctorates after graduation is by no means linear. The doctoral degree has to be viewed as one-time evidence that an individual possesses the basic competencies for problem detection and solving with new knowledge and technical approaches. Still the pure existence of this evidence does not imply that these competencies are used and applied and also not that the doctorate is capable of using these repeatedly to the fullest extend automatically, particularly in the contexts of rapidly changing socioeconomic environment and technological landscape.

Having said this it becomes clear that an academic degree such as the doctoral diploma provides an indication of the formal qualification level of the labor force in statistical sense, but the formal recognition of qualifications can hardly express the actual scientific, technological and innovation contributions made by doctorates during their education and careers. Eventually there arises a need for a new paradigm of doctorates which extends the traditional perception from ‘new academic knowledge’ towards ‘new knowledge and soft skills and competencies’ which finally enables PhD graduates entering multiple career paths (Kobayashi 2011). Accordingly doctoral studies should provide students with competencies to detect holistic pictures of research fields and also equip them with freedom and space to approach well defined problems which are clearly described and embedded in the overall umbrella topic (Goossens 2012; Huisman and Naidoo 2006; O’Carroll 2012; Shmatko and Katchanov 2014).

It is widely accepted that doctoral studies graduates are one important determinant for nations’ future scientific and innovation excellence which is assumed to result in economic competitiveness (Devos and Somerville 2012). Unsurprisingly training in innovative entrepreneurship has become a key priority for multiple lifelong learning programs and networks supported by universities, industry, venture companies, and regional authorities. In terms of personal qualities, successful innovators, to a large degree, exhibit entrepreneurship, leadership, self-confidence, and creativity. Interestingly, unsuccessful innovators have similar psychographic profiles, but their skill range is more restricted. This similarity implies that the innovative potential of an individual and essential skills for innovation can be learned (Gokhberg and Poliakova 2014).

Still scientific progress and innovation result from peoples’ ability to identify challenges and develop relevant responses. The latter requires skilled professionals who are equipped with multiple competencies, e.g. knowledge and abilities to use knowledge, which are typically trained even at primary and secondary educational level. Eventually this is the basis for doctoral graduates who are expected to generate new knowledge which is supposed to contribute to next generation innovation (Greenlee et al. 2015). In this respect one might argue that doctoral education is free in mindsets to generate any kind of knowledge without restrictions. However experience shows that even knowledge generation at doctoral education is limited by different factors. Among them the funding of doctoral students is an important dimension, but at least equally the relationship between the doctoral student and supervisors and allied scientific schools which means that doctoral students are frequently challenged by the boundaries of institutional knowledge production patterns (Carayannis et al. 2015; Devos and Somerville 2012). The actual perception of doctoral programs implies that respective research makes an original contribution to existing knowledge but the increasing pressure on institutions to meet targets imposed by the 'Knowledge Triangle' style evaluation indicators forces universities to redirect doctoral activities stronger towards applications which makes the assessment of their unique and original scientific outputs more difficult. The latter is ever more striking because the number of positions in R&D-performing organizations also for doctorates is limited (Meissner 2015; Shmatko 2014).

However the recent changes and policy initiatives in doctoral education and training should be treated against the overall trends in the evolution of skills and human capital development which form the basis of the NIS research infrastructure. For policy makers numerous options appear to influence the contribution of doctorates to scientific, technological and innovation progress made in countries:

- Attracting qualified labor to a country is a short term solution if a shortage in highly qualified professionals appears. For a limited period international skilled immigrants can fill the existing national gaps but policy needs to be aware of the global mobility of highly qualified personnel, the international competition for them and the fact that even though incoming staff might settle in the country permanently the shortage in qualified workforce will reappear when those immigrants withdraw from the labor market. Therefore this should be considered an emergency measure but not replacing restructuring efforts especially within the academic sector.
- Lasting orientation on attracting highly qualified labor force from other countries leads to the increasing dependence of the recipient nation on the international labor market. This involves the inherent danger that the international labor market might change rapidly with other countries providing more attractive employment, work and life conditions for skilled professionals. Moreover, the mobility of highly qualified labor is very high, and doctorates are frequently engaged in networks and communities which are important for transporting informative messages, assessments and images of locations. For this reason, nations with a significant share of internationally recruited highly qualified personnel are vulnerable towards positively changing environments in other countries leading to a drain of this labor to external destinations. Foreign talent can create an initial momentum in a country but cannot substitute national efforts and investments into growing and keeping national talent.
- Doctoral studies, namely doctoral thesis's are highly specialized activities which elaborate on narrowly defined topics. Doctoral graduates at their early career stages possess sophisticated but specialized knowledge which allows understanding of more general phenomena and challenges only partially. In this regard

doctorates are capable of dedicated niche work but may lack understanding of complementary knowledge and technology fields. At the same time knowledge-based companies and organizations increasingly require talent competent in researching, analyzing and synthesizing new knowledge which goes beyond the individuals' actual education.

- Innovations are increasingly a result from integrated efforts by industry and the service sector with ever more emphasis on design and communication and the human–machine interface. This requires additional competencies by researchers relating to interdisciplinary work with colleagues with fully different educational and professional background, and broader understanding of innovation and technology itself and the relation of these to society and the acceptance of innovation by the public.

Policy responses to meet the challenges imposed on doctorates can take many shapes. However policy responses and respective measures need to take account of the specificities of the NIS and the broader education system in order to become effective instruments.

- Education and training of the labor force needs to be strong at all educational levels. Especially the education field is one policy area which requires special caution and attention when it comes to changes in the primary and secondary education. Policy makers have to be aware that in these fields the basics of the labor force qualifications and skills are laid.
- Highly skilled staff recruitment policies should be based on equal opportunities, diversity, permeability, and complementarities. Equal opportunities need to consider the competencies of people regardless personal features like gender, religion etc.
- Clear responsibilities within the political establishment of nations for the advancement of young doctoral graduates are essential.
- Structural changes in the academic system are required for countries which experience 'brain drain', e.g. when more doctorates leave countries than migrate to these countries. It is often required to ensure reasonably attractive career opportunities to doctorates which include more long-term professional positions.

Development of young professionals needs to be sustainable with rather constant long-term horizon focused framework conditions. Supporting young highly skilled professionals involves all levels of education with special emphasis on promoting rigor and curiosity, risk attitudes and tolerance for failures as well as an entrepreneurial mindset relating to willingness to enter new paths outside established routines (Gokhberg and Meissner 2013). Educating such competencies from the early ages on is undoubtedly an asset for future doctorates which very likely prepares them for a challenging work life characterized already currently by increasing speed of change. However the role of policies in these matters is arguably limited since these features refer to the characteristics of individuals, hence their families' responsibility to educate and raise future doctorates personalities. Still policy can influence this process by designing the appropriate framework in which individuals grow. The importance of this aspect for policy makers is not about designing and implementing policy measures but instead being aware of this critical aspect which has definitely significant impact on the future labor force. Moreover it requires a paradigm shift from viewing measures related to these issues as cost factors or measuring the immediate impact of them. On the contrary such measures are long term investments with the typical investment characteristics of uncertainty if the investment pays off eventually.

Subsequently educational policy actions at all levels have to be sustainable measures which take account of the satisfaction and wellness (alternatively happiness) of the population and families especially. It is particularly important for individuals and families who search for environments to grow and prosper. This in turn requires reliable and stimulating framework conditions which although sustainable in nature are of course subject to improvements and ongoing refinements contributing to more and more inspiring and satisfying conditions.

Support schemes targeting at promoting young professionals need to assure that quality and diversity as well as openness and complementarities are assured. Such schemes will allow an individual to choose educational tracks which are most suitable for the person's interest and competencies and develop in a free and flexible manner. Although diverse and targeted support schemes create additional administrative burden on funding agencies they provide flexibility to fine-tune selected features of the NIS according to the respective needs (Meissner 2014).

A strong and future oriented national educational system will also emphasize the importance of exchange and cooperation between the different levels of education. Some countries practice guest speeches by scientists in secondary schools for long time with the aim of preparing schools for tertiary education. Another dimension might be the extension of doctoral programs by courses which oblige doctoral students to communicate with those at secondary and possibly even primary level by introducing science and a research profession. Such an initiative brings positive effects to doctoral students since they are forced to communicate their actual work and the basics of scientific activities and knowledge generation. It is common wisdom that scientists are usually not confronted with explaining their operations in the scientific community but frequently face serious problems with the communication to a general audience outside their professional networks. The communication skill with different audiences however is among the core competencies required for successful and efficient activities towards innovation.

Support measures for young professionals in such a shape are separate from targeted measures which aim at closing gaps in the supply of labor force in selected areas. The latter are intended to provide short term impact but experience shows that the demand for skills is hard to predict even in the mid-term which is why supply of professionals with these sophisticated competencies is difficult to develop according to the patterns of the then labor market. In this regard the general untargeted but flexible support measures respect the individual development path which is often oriented at the expected demand and needs of the labor market. Policy makers should follow basic principles:

- A future oriented education policy including support of young highly qualified professionals builds on self regulation of market forces and especially critical of self regulation of the society. Policy enforces quality control mechanisms for training and education of doctoral students which has to be rooted at the bottom as a principle. To develop human skills at this early career stage trust in the competencies and performance is of utmost importance meaning that trust-building evaluation approaches should be preferred over the quantifying ones. The frequently discussed social skills of doctorates are more realistically mirrored in personalized evaluations than in quantified indicators.
- Highly qualified labor support needs to start early in the early child education and training. This has been widely accepted and discussed but as a matter of fact policy measures in most countries match the overall span of education and training at the different stages.
- Developing promising highly qualified labor requires also financial provisions for the most promising talents. It often appears that promising students enter the first level of tertiary education but have to leave further programs due to financial obligations and allied family and individual reasons.
- For filling gaps of highly qualified people in the national labor market international recruitment can be one solution for in the short term. However such initiatives need to be planned carefully including profound analysis of the global market trends particularly relating to the national employment and work conditions for the skilled professionals. When designing respective policy measures it needs to be taken into account that especially doctorates are very mobile.
- Being mobile, doctorates typically require well developed infrastructures at the place of residence. Moreover they are engaged in their scientific communities which act as catalysts and information hubs about the quality of locations and their respective attractiveness. This is important to consider for policy makers when it comes to changing the local conditions affecting the private life of doctorates in one way or another.
- In line with the steady increase of doctorates there is evidence that especially women and younger doctoral graduates experience lower wages and are confronted with greater unemployment rates than male doctorates. Also male PhD holders are more frequently employed with fixed term contracts than their counterparts.

In sum it can be concluded that the studies provided in this book give a valuable insight into the career paths of doctorates in many different countries. From these observations, recommendations can be drawn which relate to policy making referring to the development of labor force and the national labor markets, especially with regard to education and training of doctorate holders. Furthermore it contributes to a more thorough understanding of the importance of doctorate holders for the functioning of the ‘Knoweldge Triangle’ within national innovation systems and measures to strengthen the links between various actors within them. It is clear that currently a mixed understanding of the careers of doctorates and their intrinsic motivation and ambitions exist in public opinion but also in the perceptions of policy makers.

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References

Carayannis EG, Meissner D, Edelkina A. (2015) Targeted innovation policy and practice intelligence (TIP2E): concepts and implications for theory, policy and practice. J Technol Transfer doi:10.1007/s10961-015-9433-8

Devos A, Somerville M (2012) What constitutes doctoral knowledge? Exploring issues of power and subjectivity in doctoral examination. Aust Univ Rev 54(1):47–54

Gokhberg L, Meissner D (2013) Innovation: superpowered invention. Nature 501:313–314. doi:10.1038/501313a

Gokhberg L, Poliakova V (2014) Innovative activities and skills. In: Dutta S, Lanvin B, Wunsch-Vincent S (eds) The global innovation index 2014. The human factor in innovation. Fontainebleau, Cornell University, INSEAD, WIPO, Ithaca, NY, Geneva, pp 93–99

Goossens M (2012) What career in industry for engineers with a PhD? CLAIU-EU conference “The Engineering Doctorate”, Madrid, 9–10 Feb 2012. http://claiu.fabi.be/home/wp-content/uploads/2011/12/SEII-CLAIU-2012-Paper-Marc-Goosens1.pdf. Last accessed 25 Jun 2015

Greenlee AJ, Edwards M, Anthony J (2015) Planning skills: an examination of supply and local government demand. J Plan Educ Res 35(2):161–173

Huisman J, Naidoo R (2006) The professional doctorate: from Anglo-Saxon to European challenges. High Educ Manag Policy 18(2):1–13. doi:10.1787/hemp-v18-art11-en

Kobayashi S (2011) The PhD as a professional: current status and issues concerning the early careers of doctorate holders. Jpn Labor Rev 8(4):46–66

Meissner D (2014) Approaches for developing national STI strategies. STI Policy Rev 5(1):34–56

Meissner D (2015) Public-private partnership models for science, technology, and innovation cooperation. J Knowl Econ doi:10.1007/s13132-015-0310-3

O’Carroll C et al (2012) The PhD in Europe: developing a system of doctoral training that will increase the internationalisation of universities. In: Curaj A, Scott P, Vlasceanu L, Wilson L (eds) European higher education at the crossroads. Springer, Dordrecht, pp 461–484

OECD (2011) Skills for innovation and research. OECD Publishing, Paris

OECD (2012) Transferable skills training for researchers: supporting career development and research. OECD Publishing, Paris

OECD, World Bank (2007) Cross-border tertiary education: a way towards capacity development. The World Bank/OECD Publishing, Paris/Washington, DC

Powell K (2013) Higher education: on the lookout for true grit. Nature 504:471–473. doi:10.1038/nj7480-471a

Shmatko N (2014) Research teams’ human capital. Series: science, technology and innovation WP BRP 32/STI/2014. Higher School of Economics, Moscow. http://www.hse.ru/pubs/lib/data/access/ram/ticket/34/14386992415bace2c8307475951fcb9af47471bbc0/32STI2014.pdf

Shmatko N, Katchanov Y (2014) Complexity-based modeling of scientific capital: an outline of mathematical theory. Int J Math Math Sci 2014:1–10. doi:10.1155/2014/785058, ID 785058