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MAPPING OF THE PhDs IN THE PRIVATE SECTOR

A Literature Review

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ABSTRACT: This review maps out the labour market situation of PhDs employed in the private sector. To begin with, the theoretical motives for employing PhDs and the supporting empirical evidence are examined. The potential benefits of companies from employing PhDs can be divided into productivity and innovation effects as well as knowledge contributions from networking, and external effects. Next, the international empirical literature on PhDs in the private sector is surveyed. The mostly US based research focuses primarily on PhDs in the fields of science and engineering. It provides no synoptic picture of the employment situation of the PhDs in the private sector and leaves a need for further research. A more detailed review of the Finnish literature shows that the private sector employs only about 15% of all PhDs in the Finnish labour market. There is, however, large variation between different fields of study, genders and age groups. The rapid increase in graduating PhDs in recent years indicate that the employment patterns of PhDs might be changing. Further research is needed to answer questions like: How has the increased supply changed the labour market situation of PhDs? Has the role of the private sector as an employer of PhDs changed? And is the allocation of PhDs between fields of study efficient? Another issue that has earned only very little attention is the mobility of PhDs in the labour market. Mobility within and between sectors is very important for both the diffusion of knowledge in the economy and the development of the career and wage profiles of PhDs. Because of the recent development, the existing knowledge gaps and the rapidly ageing research conducted up to this day, there is, thus, an urgent need for further research in this field.

Keywords: PhDs, private sector, career, wages, employment

JEL Codes: J24, J44, J6

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TIIVISTELMÄ: Tämä kirjallisuuskatsaus kuvaa tohtoritutkinnon suorittaneiden työmarkkina-asemaa yksityisellä sektorilla. Aluksi tarkastellaan teoreettisia perusteluja palkata tohtoreita sekä näitä teorioita tukevaa empiiristä tutkimusta. Potentiaaliset hyödyt tohtorin palkkaamisesta ovat tuottavuus- ja innovaatiovaikutukset, tietämyshyödyt verkottamisesta sekä ulkoiset vaikutukset. Seuraavaksi tarkastellaan kansainvälistä empiiristä kirjallisuutta tohtorien sijoittumisesta yksityiselle sektorille. Käytettävissä oleva tutkimus muodostuu pääasiallisesti Yhdysvalloissa toteutuneista tutkimuksista, jotka keskittyvät luonnontieteiden ja tekniikan tohtoreihin. Olemassa olevat tutkimukset ovat puutteellisia ja vaativat lisää tutkimustyötä. Tarkempi tarkastelu suomalaisesta kirjallisuudesta paljastaa että ainoastaan noin 15 % suomalaisista tohtoreista on palkattu yksityiselle sektorille. Vaihtelua oppiaineiden, sukupuolten ja ikäryhmien välillä on kuitenkin olemassa. Viime vuosien aikana valmistuneiden tohtoreiden määrä on kasvanut nopeasti, mikä vaikuttanee heidän työmarkkinasijoittumiseensa. Lisää tutkimustyötä tarvitaan vielä jotta saataisiin vastauksia kysymyksiin kuten: miten lisääntynyt tarjonta on vaikuttanut tohtoreiden työmarkkinatilanteeseen? Onko yksityisen sektorin rooli tohtoreiden työnantajana muuttunut tarjonnan lisääntymisen seurauksena? Onko tohtoreiden allokointi eri koulutusalueiden välillä muuttunut? Tohtoreiden liikkuvuutta työmarkkinoilla on tähän asti tutkittu aika vähän. Tohtoreiden liikkuvuus sekä sektorien sisällä että niiden välillä on tärkeää tietämyksen levittämisen ja tohtoreiden palkkakehityksen kannalta. Johtopäätös on, että enemmän tutkimusta tarvitaan puutteellisten ja vanhentuneiden tietojen takia.

Avainsanat: tohtorit, yksityinen sektori, palkat, ura, työllistyminen

JEL koodit: J24, J44, J6

1 Introduction

The last 20 years or so have been very eventful in the Finnish labour market for PhDs. In the 1980's, the number of PhDs graduating per year was low and had only been increasing very slowly. This was partly due to a poorly structured education system that did not enable PhD students to graduate very quickly (Husso 2005a). At the same time the demand for PhDs had increased, especially in private firms. Nokia, followed by other companies and banks, established supplementary education programmes in cooperation with universities in order to enhance the educational level of their employees. The magnitude of these programmes varied and they were never large in scale, but they sent important signals to policymakers that the education system needed improvement (Husso 2005a).

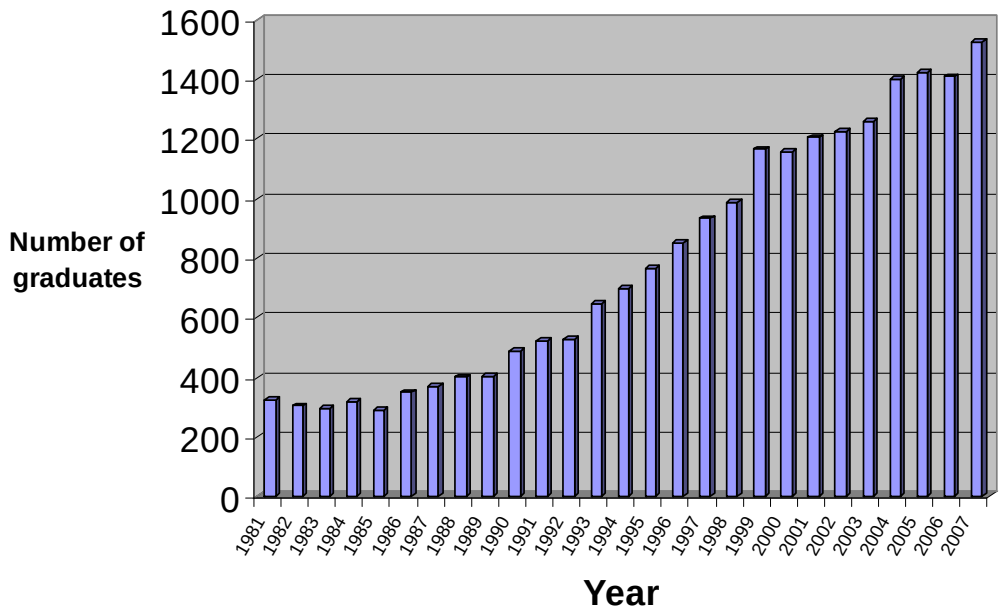
Moreover, in the beginning of the 1990's, there was a change both in the international and the national attitude towards research (Husso 2005a). This was the time when interest in the knowledge-based economy[1] increased. In the spirit of this period, the creation and diffusion of knowledge within the country was considered to be an important competitive advantage. Since then, in hope to further stimulate economic growth, plenty of effort has been put into understanding the relationship between scientific research, technological development and innovations (se for example The Knowledge-based… 1996). This development thus further helped address the need for improvements in the doctoral education system.

As a result of these developments, a system with doctoral programmes was established in the Finnish education system in the mid 1990's. The doctoral programmes were planned to be the postgraduate student's main occupation and last for four years. The doctoral programmes were established for the most important fields of study and were organized in cooperation between different universities. In 1995 there were 69 graduate schools with 722 postgraduate students (Husso 2005a). In 2005, the corresponding numbers were 124 graduate schools with public financing and about 4,500 students of whom 1,458 received financing from the Ministry of Education in the form of a grant (Universities… 2007). The education of postgraduate students is mainly financed by the universities, The Academy of Finland and the Ministry of Education. Financing is also obtained from other instances, such as foundations and compa-

[1] The knowledge-based economy is an economy that is directly based on the production, distribution and use of knowledge and information (The Knowledge-based… 1996)

nies. As the doctoral programmes were established, the number of graduated doctorate holders started to increase. From 1995 to 2007 the number of PhDs who graduated each year doubled from 765 to 1,524 and the number is still rising (KOTA 2008).

Figure 1. Graduated PhDs in Finland 1981-2007



Source: The KOTA Database, 2008. The Ministry of Education.

Soon after the yearly graduation rate of PhDs had started to increase, the question whether Finland now educated too many PhDs was raised. In order to answer this question, the Finnish Ministry of Education appointed a number of committees to investigate how the postgraduate education system could be further developed and the need for PhDs in respective fields (Kestävä… 2005). The main conclusion of these committees is that there is no overproduction of PhDs in Finland, and that especially in the field of engineering the education of PhDs should be increased further (Poropudas 2004). This large demand for PhDs is partly motivated by the forthcoming change in the demographical structure of the PhD labour force. Poropudas (2004) estimated that in 2000-2020 15,600 researchers (both PhDs and licentiates) will leave the labour force, which is about 80 percent of all employed researchers in 2000. Another motivation is the increased demand for highly skilled workers that is due to the transition into the knowledge-based economy (Tohtorikoulutuksen… 2006). By 2020 the demand for researchers will have increased from 19,000 in year 2000 to more than 40,000 (Poropudas

2004). The goal is that 1,600 PhDs will graduate in 2008 (Tohtorikoulutuksen… 2006) and that in 2012 the number of doctorate students with financing from the Ministry of Education will have increased to 2,000 (Koulutus ja tutkimus 2008).

Table 1. Number of PhDs who graduated in 1995-2006 according to field of study.

Field of Study	Year of graduation					
	1995		2000		2006	
	Total	Females (%)	Total	Females (%)	Total	Females (%)
All fields	786	288 (36,6)	1 142	518 (45,4)	1 411	660 (46,8)
Natural Sciences	179	62 (34,6)	245	99 (40,4)	294	115 (39,1)
Engineering	114	13 (11,4)	152	29 (19,1)	286	57 (19,9)
Medicine and Health Sciences	221	114 (51,6)	330	201 (60,9)	316	201 (63,6)
Agronomy and Forestry Sciences	22	8 (36,3)	43	17 (39,5)	58	29 (50,0)
Social Sciences	168	57 (33,9)	234	111 (47,4)	315	181 (57,5)
Humanities	82	34 (41,5)	138	61 (44,2)	142	77 (54,2)

Source: Statistics Finland 2007.

Despite this rapid development, we know very little about the PhDs and their labour market situation and placements. While the need for PhDs in Finland has been studied in the past at least to some extent, we know less about the actual placements of PhDs in the Finnish labour market and how their situation has developed since the reformation of the education system. The aim of this review is to map out what we know today about the labour market situation of PhDs, nationally and internationally. We restrict the review by focusing on the PhDs employed in the private sector only.

The PhD degree is interesting because it is the highest academic degree and because PhD graduates have skills that differ from the ones of holders of lower degrees. PhDs are trained to do research and have vast knowledge in their field of study as well as specialized knowledge in some part of it. Because of these skills, PhDs are often working with research and devel-opment (R&D), either in universities, research institutions or compa-

nies. PhDs are thereby assumed to increase the pace of innovation[2] and thereby the productivity of a firm or an economy.

University research is undoubtedly important for new discoveries and inventions. However, the real driving forces for commercially valuable innovations can be assumed to be located in the private sector. The main task of universities is to pursue basic research, for the sake of science. The private sector, on the other hand, is driven by the urge to make profits. Therefore, in the private sector, competition between firms accelerates the pace of innovation more than in the university sector. It is this supposed larger influence on economic and technological development that motivates our interest in PhDs employed in the private sector.

We begin this review by examining the theoretical motives for firms to hire PhDs and the supportive empirical evidence. In other words, we aim at identifying the potential benefits from employing a PhD. It is shown that PhDs can potentially contribute to enhanced firm productivity in several ways and that these effects may be of substantial size.

After having studied the theoretically derived benefits to firms from employing PhDs, we move on to study the actual labour market placements of the PhDs in the private sector. The aim is to see to what extent the private sector makes use of the resources wrapped up in PhDs. First we review the international literature, and then we focus more closely on the PhDs in the Finnish labour market. Given the potential gains set out by theory, the private sector should be an important employer of PhDs. However, this does not seem to be the case. In Finland, the private sector is the third largest employer of PhDs after the universities and the municipalities, closely followed by the government sector. In total, the private sector employs about 15 percent of the doctorate holders (Haapakorpi 2008; Husso 2005b).

The aim of this paper is, as mentioned earlier, to review what we know this far about the labour market situation of the PhDs employed in the private sector this far. We hope to draw some conclusions on the potential benefits of PhDs, as well as the degree to which firms make use of them in practice. But rather than serving as support for future policy making, this re-

[2] Innovations are a frequent subject of study in economics and there are numerous definitions of the term. To summarize the concept: an innovation is the introduction of a *new* product, method, technology or similar that increases economic value for the producer or/and the costumer (see e.g. Black 2003). Innovations should not be confused with inventions or discoveries that are new ideas, but do not (yet) possess economic value.

view surveys the current state of research in this field, illuminates its shortcomings and gives ideas for future research.

This paper is threefold. Section 2 in this review explores the theoretical justifications for a private sector firm to hire a PhD and the supporting empirical evidence. Thereafter, section 3 surveys the international literature on PhD placement in industry in order to map out what is known this far and what is still not researched. In section 4 the employment situation of the PhDs hired by the Finnish private sector is studied more closely. Section 5 concludes by summarizing the present state and discusses outlines for future studies.

2 Justifications for employing a PhD

When studying PhDs employed in the private sector and the utility of them, it is of great relevance to look into how the employment of them is justified. In this section we will focus on the theoretical motives put forward for the private sector to hire PhDs, and examine if there is any substance behind these motives, in the form of supporting empirical evidence.

One distinct motivation for employing a PhD is the knowledge that he or she possesses. The PhD degree is the highest academic degree attainable, and its framing differs from those of lower university degrees. In addition to their knowledge in their field of study, PhDs are trained to do research, which provides them with special types of skills. In the literature, especially one kind of knowledge, tacit knowledge, is emphasized to be attractive for the private sector (Stephan et al. 2004a; Stephan 2006; Zucker et al. 2002).

Knowledge can be divided into several different types of which codified and tacit knowledge are the most important in this context (Dosi 1988). Codified knowledge can quite easily be shared, for example through writing in publications or patents. It is a formal kind of knowledge that is available to practically anyone who is interested in it and can find it. Tacit knowledge is more informal in nature. It is hard to define and cannot necessarily be shared in writing. Thus personal contact is often needed when passing it down. As a consequence, tacit knowledge is often spread through seminars, meetings, networks and collaborations. Tacit

knowledge is often described as know-how or as a tool needed for using codified knowledge (OECD 1996). The importance of tacit knowledge is often stressed in the literature but still only few attempts have been made to actually measure tacitness. One try to locate the presence of tacit knowledge in biotechnology was made by Zucker et al. (2002), when they defined a measure of knowledge tacitness. They argued that tacitness in a field is high if a young researcher often publishes together with an older co-author instead of publishing on his own.

A substantial part of the knowledge that a newly graduated PhD possesses is tacit in nature (Stephan et al. 2004a). For example, this knowledge could take the shape of new techniques or procedures that he/she has learned while working in his/hers supervisor's lab in graduate school. It is this tacit knowledge that is particularly interesting for the private sector, as it can be hard to obtain otherwise. In the private sector this is a strong motivator for employing PhDs, and especially recently graduated doctorates, as their knowledge is most up to date.

Cohen, Nelson and Walsh (2002) tried to estimate the importance of PhD hires in the private sector. They asked R&D managers in private firms which factors had been at least "moderately important" for completing major R&D projects recently. In total, hiring recently graduated PhDs had been of at least moderate importance in 19.6% of the cases. This denoted a considerably smaller impact than the one of publications and reports (41.2%), which was the path with most impact. This could be interpreted as if firms already have a strong PhD capacity, since they manage to benefit from publications so well. However, there was considerable disparity between different industries. Recently hired PhD graduates seemed to play a relatively bigger role in pharmaceutical, mineral, glass and concrete industries, electronic components industry, communications equipment and computer industries, even though publications and reports also played a bigger role in these industries. In line with the argument above, tacit knowledge might be more important in these fields. This study does not reveal in what ways the PhDs helped in completing the projects. Nevertheless, it shows that PhDs are useful resources for the private sector R&D.

2.1 Productivity and innovation effects

Next we will study in which ways firms can make use of the PhDs that they employ. Human capital theory, which has sprung from the work of Jacob Mincer (1974) and Gary Becker (1964), can help explain how the benefits from employing PhDs take form. This literature

argues that human capital is a factor of production, just like physical capital, and that individuals can invest in human capital through e.g. education. The investment in education makes the worker more efficient, and thus it yields additional output that both the employer and the employee can benefit from. The employee receives his/her return from the investment through higher earnings and the employer, on its turn, expects the increased level of human capital to result in growth in company productivity. According to this reasoning, employing a holder of a PhD is an investment in labour efficiency that can improve the productivity of the employing company.

Nelson and Phelps (1966) argue that the productivity enhancing effect from education works in two ways. The first is, as discussed above, through making use of *existing* machinery or technology more efficiently. These productivity effects are, however, decreasing as the educational level increases, as it is only possible to exploit available machinery up to a certain point. The other productivity effect, introduced by Nelson and Phelps, works through creating and implementing new technologies in the company (see also Benhabib and Spiegel 1994). They argue that highly educated persons, such as PhDs, can increase firm productivity through *changing* and *developing* machines and technologies. As technology always can be improved, the marginal utility from this productivity effect is not decreasing. As PhDs are trained to do research, handle complex problems and think in new and creative ways, if working in the private sector, they are suitable for working with R&D. In these kinds of tasks they are likely to take part in innovative activities, creating new products and procedures for their firm (Stephan 2002; Zucker and Darby 2001). Because of the nature of innovations, that is the long time it takes to develop and implement them, the increased productivity that stems from development of new techniques is occurring with a lag (Nelson and Phelps 1966; Maliranta 2003; Rouvinen 2002).

In a study using Finnish linked employer-employee data Maliranta and Asplund (2007) studied the effects of highly educated personnel on firm productivity. They found that new university hires initially had a strong negative impact on firm productivity, but that they in the long run markedly contributed to firm productivity growth. This supports the hypothesis of Nelson and Phelps that rather than being only factors of production, highly educated workers are factors of technological change and productivity growth. The results of Maliranta (2003) point in the same direction. He studied productivity growth effects of highly educated workers on the plant level in Finnish industry and found that improvements in productivity growth resulting

from an increased skill level in the plant do not occur directly, but with a considerable lag. Maliranta found that this seemed to apply especially to education earned in the fields of science and engineering[3]. All of these findings suggest that there are indeed productivity enhancing gains from highly educated workers, and thus PhDs. We point out, however, that these studies did not explicitly study doctorate holders, but highly educated (university degree holders) individuals in general.

Daveri and Maliranta (2007) studied the effect of education on productivity in three different branches in Finnish industry. They found that the impact of education on productivity differs between industries, so that the technological level of the industry seemed to be essential for the size of the productivity effect. In electronics the effect of education was positive and larger than in industrial machinery. In the forest industry no clear-cut relation between education and productivity was found. Furthermore, education was found to increase productivity with a two-year delay. It seems that not all fields of study are equally important when enhancing productivity.

Another interesting contribution to this literature is the one of Bartel and Lichtenberg (1987). Partly based on Nelson and Phelps (1966) they formed a hypothesis that highly educated workers have comparative advantages with respect to the implementation of innovations. Based on this, they argue that in the adjustment to new technology highly educated workers are needed. Consequently, industries with high innovation rates should have the highest demand for highly educated workers. Similarly, the demand for highly educated workers should vary over time, so that the demand is highest in the beginning of a firm's life cycle when technology is implemented. Their empirical analysis found support for this hypothesis, showing that the relative demand for educated workers declined as the capital stock (rather than the plant) ages. This supports the idea of Nelson and Phelps that the highly educated, among them the PhDs, are important for the implementation of technology and that their effects on productivity occur with a lag. Moreover, the utility of PhDs may vary over the life cycle of the firm.

[3] The term science and engineering comprises the fields of life sciences, physical sciences, mathematics, computer science, earth sciences and engineering. The life sciences of their part are medicine, health science and biology.

Maliranta et al. (2008) studied the spillover effects of inter-firm R&D labour mobility on productivity and profitability using Finnish employer-employee data. Somewhat surprisingly, they found that hiring personnel from a R&D lab to your own lab has no positive effects on either productivity or profitability. When hiring workers previously in R&D to non-R&D activities, however, there are significant positive effects on productivity and profitability. This is interpreted as indicating that the knowledge that the workers transmit can be copied and implemented without much additional R&D efforts (Maliranta et al. 2008). The approach in itself is very interesting, but it is not clear to what extent it can be utilized to study the productivity effects of hiring PhDs. Only about 3 percent of the Finnish private sector R&D labour force are PhDs (Suomen tieteen… 2003), and therefore R&D workers are quite a poor proxy for PhDs.

Yet another possible productivity enhancing effect of doctoral education is that the PhDs in a firm produce positive spillovers that affect the productivity of the less educated workers (i.e. they share their knowledge with their co-employees). Moretti (2004) found some evidence pointing in this direction when studying how the proportion of college graduates in US cities affected the wages of less educated individuals. He found that a one percent increase in the proportion of college educated individuals increased the wages for lower educated workers with up to 2 percent. The productivity spillovers from PhDs within firms have thus far not been empirically studied.

Very closely related to the productivity growth argument is the argument that PhDs contribute to innovations. Innovative activities, by definition the invention, commercialization, and diffusion of new products, processes, and services, are not as easily measured as, for example, productivity. Traditionally, university or industrial R&D expenses and patenting have been used as proxies for innovations on a national level. Lately, however, it has been argued that the traditional innovation measures are becoming steadily less able to illuminate national innovation patterns (Mowery 1999; Stephan 2002). This is due to four structural changes in innovation patterns expressed by Stephan (2002). The first is the increased role of privately funded R&D. The US industry funded two thirds of the R&D in 1998 and the share had been increasing for two decades and still was. The corresponding percentage for Finland was 71.3% in 2006 (Statistics Finland 2007a). Second, there has been a change in the distribution of innovative activities, meaning that the service sector i.e. the non-manufacturing industries make up for a larger share of R&D performance than before. The US service sector accounts

for 25 percent of the industrial R&D expenditures but employs about 45 percent of the scientists and engineers employed in industry. Third, a shift away from ‘research’ and towards ‘development’ has occurred. In 1997, 80 percent of the industrial R&D expenditures were directed towards development in the US. Fourth, and last, there has been a change in the organization of research. This means that (1) industry more frequently relies on external R&D (Mowery 1999), (2) industry collaborates more with competitors and customers in the development of new products and processes (Mowery 1999), (3) a decentralization of in-house R&D activities has taken place and (4) innovative activities have been moved to functions in the firm not typically involved in R&D (Stephan 2002). All of these changes, and especially the fourth, contribute to making the innovation systems more complicated and blurry. Therefore, Stephan suggests that data on the deployment of PhDs should be used as a complement to the traditional measures of innovations, when studying the national innovation patterns. This initiative shows that PhDs play a significant role in innovative activities. Also, the argument made by Stephan further stresses the importance of collecting data on how PhDs are deployed in the labour market.

2.2 Networking

It has also been argued that PhDs can improve firm performance through participating in networks consisting of professionals from other sectors and firms. Networks are typical means through which tacit knowledge can be shared. Powell et al. (1996) argued that inter-organizational networks are the cradle of innovations, especially in fast growing technology industries, such as biotechnology. In a related study networking was proved to improve firm performance even if the returns to collaboration were decreasing (Powell et al. 1999). Because of their close relationship with their home university and other recent graduates, hiring recently minted PhDs is seen as a good way to maintain old and build up new networks between the private and public (i.e. university and government institutions) sectors. However, the positive effects of networking cannot be attributed to recently graduated PhDs alone.

Zucker and Darby (2001) took on a different approach as they studied the productivity enhancing effects of cooperation between biotechnology firms and Japanese star scientists, meaning particularly successful scientists employed in the academe. It was shown that firms that collaborated with star scientists were affected positively so that on average their biotech patenting was increased by 34 percent and their products in development by 27 percent and on

the market by 8 percent. Despite the differing focus, we can conclude that firm productivity can be improved by collaboration with highly educated individuals, among them PhDs.

Leiponen (2000) suggests that higher skills in the firm contribute to absorptive capacity, meaning the firm's ability to embrace external research (see also Cohen and Levinthal 1990). Therefore, firms with different kinds of skills engage in different kinds of R&D collaboration. She finds that research competence is important for collaboration with universities, but less important in collaboration with competitors. Furthermore, firms with more skills tend to outsource R&D more often. In this context, hiring PhDs can be seen as a means of getting access to, understanding and making use of external research. Stephan (2002) gives an example of a more extreme version of this phenomenon in the company Cisco Systems, where scientists do not themselves perform R&D activities but assess the R&D capabilities of possible acquisitions.

2.3 External effects

In addition to positively affecting the performance of a firm, employing PhDs might also have a positive effect on the economic development in the region in which the PhD is employed. The effects are probably similar to the ones on company level; as more knowledge is accumulated in the area, the regional productivity increases as well as the pace of innovation. The regional effects could, in total, be larger than the direct firm effects, as other external regional level effects also arise and, hence, are accounted for. For example, PhDs earn high wages, which leads to increased tax revenues in the region. They also spend most of their salaries locally, and so, the region benefits from the PhDs in many ways. Both human capital and innovative firms often accumulate in certain regions (Stephan et al. 2004a, 2004b; Sumell, Stephan and Adams 2006). In this case a region that succeeds in attracting innovative firms and PhDs can expect positive development at an increased pace compared to other regions.

There is only little evidence to be found on how the hiring of PhDs affects the region. Piekkola (2006a) conducted a study on knowledge capital as a source for regional economic growth. He found that in Finland, the education human capital is geographically agglomerated close to the Helsinki region. This is also where most of the leading industry companies are situated. The Helsinki region was shown to be 12 percent more competitive than other regions. It turned out that educational capital is an important cornerstone for productivity

growth, even if not all of the competitive advantage in this case can be ascribed to educational capital. However, educational human capital alone is not too useful, unless the firm has other forms of capital, such as occupational human capital, to go with it (Piekkola 2006b).

Another external effect of PhD education is knowledge spillovers. This literature examines the relationship between universities and firms and how the university R&D, in the shape of publications, patents and human contact, affect the performance of firms. Focus has often been on the importance of geographical proximity. The types of knowledge transferred have also been studied. Even if this certainly is a field of interest, we will not look into it here in more detail, as the subject falls outside the scope of this review. Interested readers are recommended to study e.g. Tappeiner et al 2008, Döring and Schnellenbach 2004 and the work of Jaffe (1989) and Anselin et al. (1997, 2000).

In recent years, universities have adopted a more active approach in the establishing of new high-tech firms as a consequence of the emphasis on commercializing knowledge (O'Shea et al. 2005). Many universities have encouraged their students to start companies of their own. This phenomenon is studied in the literature on university spinoffs, which are new companies that are built up around universities by talented and highly educated students. The focus of these studies has been on the characteristics of the students and the universities as well as the commercializing-practices of the universities and impacting environmental factors (see O'Shea et al. 2005). University spinoffs could be seen as a form of PhD employment in the private sector, but mainly as a form of self-employment. Therefore, this literature will not be more closely studied here.

All in all, what make PhDs important for the private sector are, without doubt, their special knowledge and their research skills. Their tacit knowledge is of particular interest as it is very hard to lay hands on. As has been shown in this section, there are many ways in which the private sector can make use of PhDs. Firstly, PhDs are seen as direct contributors to productivity growth and innovation through their work in R&D. Secondly, especially recently graduated PhDs are often regarded as springboards to networks consisting of professionals from e.g. the university sector or other companies because of their close bonds with their training university and co-students. Thirdly, PhDs can be used to search for, collect, and make use of external research (Leiponen 2000; Stephan 2002), and in this way help improve firm performance. All of these are good reasons for firms to employ PhDs. Of course, it is good to bear in

mind that neither the PhDs nor the firms in the private sector should be treated all alike. Firms in certain lines of business might benefit more from PhDs than others. We saw evidence of this in the study of Cohen et al. (2002). In a similar way, PhDs in some fields are of more use for firms. Also, it is important to point out that the existing literature on productivity and innovation effects of PhDs exclusively focus on PhDs in science and engineering. It is not clear to what extent the effects discussed above also hold true for PhDs in e.g. humanities or social sciences. Furthermore, it is worth noting that all of the studies reviewed here do not even study PhDs in particular, but rather scientists or highly educated individuals. Now that we have studied how the private sector can profit from employing PhDs, it is time to see how it is actually making use of the PhDs in the labour market. We do this simply by reviewing the deployment of PhDs in the private sector.

3 Mapping of private sector PhDs in the international literature

Although there is, and should be, a veritable interest in PhDs hired by the private sector, not much has been done empirically to find out who they are and where they work. This is at least partly due to lack of appropriate data. However, in recent years some effort has been put into mapping out both the PhDs employed by the private sector and the hiring employers. In this section we will map out what we know about PhDs employed in the private sector this far based on the international literature. To begin with, we will try to answer the questions of who the PhDs and their employers are. Then we will move on to study the mobility of PhDs in terms of both career paths and geographical moves. Finally, the situation will be evaluated and we will identify, if any, information gaps in the literature.

3.1 Deployment in the private sector

The purpose of this review is to survey the literature concerned with the labour market situation of PhDs employed in the private sector. The problem is that only very few studies have tried to answer this question. As a consequence, the empirical evidence is not very extensive. One strand of the literature studies the labour market situation of PhDs in general but, in doing so, focuses only on doctorate holders engaged in the public sector (Auriol 2007; Auriol, Felix and Fernandez-Polcuch 2007). One potential explanation for this is that the number of PhDs is considerably larger in the public than in the private sector. Another common phe-

nomenon is to focus only on the doctorate holder in the fields of science and engineering (S&E). The justification for this delimitation is that S&E PhDs are more likely to contribute to innovations and productivity growth than are PhDs from other fields. Moreover, the PhD impact on innovations has often been the subject in previous studies, rather than thorough mapping out of the labour market situation of the PhDs. All this affects the characteristics and variables actually examined in the studies.

The main empirical evidence on the PhD deployment in the private sector available is published in a series of articles concerning the USA and includes science and engineering (S&E) PhDs only (Stephan et al. 2004a, 2004b; Stephan 2006; Sumell et al. 2006). The data are collected through the Survey of Earned Doctorates (SED). The survey is directed to graduating PhDs and the response rate has been 92 percent. Information on the organization and location where the PhD will work directly after graduation has only been coded since 1997. In the period of the studies, 1997-2002, almost 22,000 PhDs reported the name of a firm, which was about 15 percent of all the respondents. There are some drawbacks to the data. One is that the number of PhDs in the private sector is understated for three reasons. Firstly, at the time of answering the survey, not all PhDs had definite plans for the future. Secondly, not all of the PhDs knew the name of their prospective employer: 37 percent of the respondents who reported that they were going to work in the private sector could not name an employer and were therefore not included in the study. Thirdly, taking postdoctoral positions directly after graduating is very common, especially in life sciences where more than 50 percent take postdoctoral positions upon graduating. Yet, roughly 30 percent of these later end up working in industry (Stephan 2006). In fact, about three times as many PhDs end up working in the private sector as do those who intend to do so at the time of graduation (Stephan et al. 2004b). Another weakness is that the data covers a short period of time and that this period was characterized by the dot.com boom and a following recession. These events might somewhat bias the results. Also, the focus on PhDs who are about to graduate, and are not even working yet, is a slightly questionable approach. Despite all the drawbacks, these studies are rare in kind in that they try to locate the PhDs in the private sector, and we can learn certain things from them.

First, during the last three decades, the US private sector has become more important as an employer of PhDs. In 1999, 38 percent of the S&E PhDs that had graduated in the last five years worked in the private sector compared to less than 30 percent 25 years earlier (Stephan

et al. 2004b). Furthermore, engineering and chemistry have had the highest percentages of PhDs in the private sector, while life sciences have been poorly represented in the private sector compared to other fields. Computer sciences and math are the fields in which the percentage of PhDs in the private sector has increased fastest (Stephan et al. 2004b).

Table 2. Firm placement of new science and engineering PhDs in the USA: 1997-2002.

	Period One (1997-1999)		Period Two (2000-2002)	
Field of PhD	Percent PhDs awarded who identified a firm	Percent going to a top 200 R&D firm	Percent PhDs awarded who identified a firm	Percent going to a top 200 R&D firm
All S&E	14,5	37,8	15,2	40,0
All engineering	30,7	44,7	31,9	47,8
Agronomy	9,0	14,9	8,2	31,2
Astronomy	7,8	36,4	6,8	48,6
Biology	3,8	23,2	5,2	24,6
Chemistry	18,7	45,0	22,2	45,0
Computer science	28,4	50,3	27,9	45,3
Earth science	12,3	29,7	13,1	31,2
Math	12,5	32,3	12,3	35,5
Medicine	5,0	20,0	5,4	26,1
Other (Economics and Psychology)	8,3	10,7	9,0	10,5
Physics	16,1	33,2	18,1	41,2

Source: Stephan 2006 (Table 3.1)

Of the PhDs who graduated in 1997-1999, 14.5 percent were employed in the private sector. However, the number varied significantly between different fields. Engineering and computer science PhDs were most often employed in the private sector (30.7 and 28.4 percent respectively), while at the other end of the spectra were medicine and biology PhDs (5.0 and 3.8 percent). The low percentage was explained by the tradition to take postgraduate positions in universities in these fields. When Stephan et al. (2004a) indentified the top 200 R&D firms, and the PhDs going there, it was found that about 38 percent of the PhDs who reported a firm were going to a top 200 R&D firm. Computer science and engineering PhDs were more likely to go there than others. Of the biology PhDs, only a small share was employed by top companies. This was interpreted as a sign of the importance of small firms in that field. The same exercise was later repeated with graduates from the period 2000-2002, with similar results (Stephan 2006). 15.2 percent of the PhDs named a firm and 40 percent of them a top 200 firm. There was a slight decrease in the number of computer science, engineering and math PhDs who listed firms, but this was probably caused by the end of the dot.com boom. During the same period both the number and percentage of biology and chemistry PhDs in firms in-

creased. This development was due to an expansion in the number of pharmaceutical firms during this period. When the companies were divided into five groups according to R&D expenses, it was evident that engineers were the largest group of PhDs employed in all firm categories. Small firms were more likely to hire PhDs from biology, agriculture and medicine, which also tells about the importance of small companies in these fields.

Firms employing PhDs were quite selective. On average firms hired two thirds of their PhDs from top institutions in the respective fields. In the top 50 R&D firms the percentage was even higher, more than 75 percent. The top 30 hiring firms employed 26 percent of all PhDs going to the private sector and 68 percent of those working in a top 200 R&D firm. That largest number of hires was located in computer programming, industrial machinery (including computers), communications equipment, chemicals and pharmaceuticals among others. The authors pointed out that the IT-boom was at its peak during the period of their study and that this was probably reflected in the large number of both employed engineers and computer scientists and employing firms in related industries. Most industries were shown to hire PhDs from four or more fields. When comparing the hiring of PhDs and company R&D expenses, it became clear that there was a positive relationship between the two, even if there were some variation. The hiring variable captures a different dimension of innovation than R&D expenditures. According to this argument presented by Stephan (2002), R&D expenditures alone fail to capture some dimensions of the innovation system.

This set of US studies gives us quite a good picture of the initial placement of PhDs in the private sector. However, it leaves some questions unanswered. To begin with, it focuses only on PhDs in science and engineering. This is motivated by assuming that PhDs in these fields are most likely to contribute to innovations. To get a better picture of the PhDs in the private sector, however, a study including PhDs from all fields would be most useful. This is of particular importance for at least two reasons. First, the structures of innovation systems are changing. This means that R&D activities are more often moved from traditional R&D departments to e.g. marketing departments or decentralized to the plant level (Stephan 2002), and consequently the personnel involved in R&D is more miscellaneous than before. Second, when making policy decisions on how many PhDs to educate it is crucial to have information on doctorate holders from all fields, not only science and engineering. Furthermore, nothing is said about the personal characteristics, like gender and age at the time of graduation, of the PhDs in the private sector.

3.2 Career mobility of PhDs

The study of Stephan and co-authors is important in the sense that it attempts to study knowledge transfer in the shape of *new* PhDs. However, the knowledge and experience accumulated by PhDs while working in the private sector or by those PhDs who move to work in the private sector only later in their careers should not be overlooked. Hence, apart from the initial transition into working life of graduating PhDs, also the career paths of doctorate holders deserve attention. Here we are interested in the mobility between and within sectors of employment, and especially the private sector. In other words we want to see what kind of knowledge and experience PhDs bring to the private sector. Furthermore, we are interested in the career paths of the PhDs, meaning their work tasks and the changes in these during their career. Moreover, of interest are also wage profiles of the PhDs, and how these vary with their accumulated experience and career mobility.

Based on existing research it is, however, hard to form a comprehensive idea of the sector mobility of PhDs, because not much is known on the subject. Of the available research not much has focused on the employment or the careers of PhD. As already noted previously, one strand of the literature has focused on firm collaborations with star scientists, who are not necessarily employed by the firm or even PhDs, though (Zucker and Darby 2001). Another line of research is that of university spinoffs, which studies new companies that are founded by former students or university personnel (O'Shea et al. 2005; Lindholm-Dahlstrand and Jacobsson 2003).

Mishagina (2007) studies career transitions of natural sciences and engineering PhDs in the USA in 1973-2001. Her approach differs slightly from our focus of interest, as she does not distinguish between employment sectors, but instead between research jobs, applied jobs and non-S&E jobs. Nonetheless, she finds that 72 percent of S&E PhDs start their career in R&D jobs and that, 30 years later, only 45 percent were still there. The career transitions are most likely to occur in the first 16 years of the PhD's career. About 8 percent were working with non-S&E jobs, such as financial or other business services, non-technology consulting or law. She moreover finds that those who also possess a non-S&E degree are more likely to leave S&E, regardless of position prior to the exit. Thereto, persons with more postdoctoral appointments are more likely to leave R&D for non-S&E. Mishagina suggests that this is due to a "discouraged worker effect", if the person has failed to get a tenure-track job. When study-

ing pay-offs of doctoral education on the aggregate level, these are interesting findings. Thus, if the doctoral education is publicly financed, then it is not likable from the view of the tax-payer that a non-negligible share of the sciences and engineering PhDs choose not to make use of their education. If the doctoral education is financed by the PhDs themselves, this can be considered as less of a problem.

There is another interesting feature to this literature. Most S&E PhDs start their careers in R&D, where the starting wages are lowest. Then, as time goes by, many drop out to applied jobs or leave S&E for good (Mishagina 2007). Meanwhile, the salaries of those who stay in R&D increase rapidly. There are many possible explanations for thee observed drop outs. Mishagina (2008) suggests that many scientists start their researching careers based on imperfect information on their research skills. When time goes by, however, they become aware of their abilities, and the ones who lack the required skills change jobs. Meanwhile, the ones who stay and consequently are good researchers experience rapid growth in their wages. Does this mean that the best researches stay in universities while the less talented move to the private sector? It is hard to say, because “R&D”, “applied jobs” and “non S&E” are, as already noted, not defined by sector of employment and, hence, cannot be translated directly to “university” or “the private sector”. If, however, such a selection occurred, would this have consequences for the private sector and its innovative activities? How are the productivity and competitiveness of a country affected if the sharpest research brains stay at the universities, while the others work in R&D in the private sector where many of the most important innovations are meant to be invented?

Other explanations are, however, less dramatic. In some fields of study, and especially in life sciences, it is common to take post-doctorate positions in the university upon graduation either because it is considered as a stepping stone to the kind of jobs they are applying for later on (most frequently, but not always, in the university), or simply because they fail to get another job. Later on, many of these postdoctoral position holders are hired by the private sector (Recotillet 2007; Stephan 2006). Yet another reason why PhDs leave university for the private sector is simply that they are lured to the company because of their knowledge. Earlier in this review it was argued that newly minted PhDs possess tacit knowledge. Zucker and Darby (2001) introduce the scarcity of knowledge to the picture, arguing that immediately after a new invention has been developed, when only the inventor knows the technique, there is knowledge scarcity. If the new knowledge is important to a firm, and tacitness and scarcity

causes the news to spread too slowly, then the firm might affiliate or employ the inventor the get its hand on the new discovery.

The mobility of star scientists in biotechnology in the USA was studied by Zucker et al. (2002). It is worth noting, though, that their approach was different because they studied star scientists, who are defined as the most cited university scientists in their respective fields, while not necessarily being PhDs. However, it was shown that star scientists start collaboration with or move to firms more quickly if they possess more "high quality intellectual human capital", which is measured by citations in published articles, and if their knowledge is more relevant to firms. The size of the star network outside the university and the number of high-tech companies in the region increase the probability that the star moves to the private sector, while the number of top universities in the region decrease the probability. Zucker et al. also found a pattern for the deployment of stars between the private and the university sector. The elite, with most citations, publications, external co-authors and experience were more likely to split their time between the two sectors while the least experienced and successful were most likely to work solely for the university. The middle group were most often working full-time in the private sector.

The finding of Bartel and Lichtenberg (1987) is of interest also in this context. As discussed earlier, they found that the demand for highly educated workers is highest in the beginning of the life cycle of a firm. The underlying reason is that highly educated workers are needed mostly for inventing and implementing new technologies, which are activities only realized once or very seldom in a firm's lifetime. In this aspect highly educated workers, and among them PhDs, mostly figure in young or otherwise innovative firms. Their mobility rate should be higher than the one of lower educated workers. To confirm this hypothesis further research is needed, though.

All in all, the available – although solely US-based – empirical evidence clearly indicates that more PhDs than those who originally plan to do so end up working in the private sector. Some effort has been put into indentifying the sector movers, but no unambiguous conclusions can be made. More extensive mapping of the career stages and paths of PhDs is still desirable.

3.3 Geographical mobility

The geographic mobility of PhDs is an interesting issue for several reasons. To begin with, we are interested in both the mobility of recently graduated PhDs and the mobility of PhDs in general both within and across national borders. As mentioned earlier, educating PhDs is a very costly task financed by the public sector in many countries. If so, an important argument for a region or a country to participate in the initiative of postgraduate education is that the PhDs later on will contribute to the economic development in that the country through their work. A necessary assumption for this argument to hold is that the PhDs stay in the country or region, or alternatively that the PhD emigration of the region is compensated with PhD immigration. The geographical mobility of PhDs is of interest also when studying innovation systems. This is an approach adapted by Stephan and her co-authors (Stephan et al. 2004a, 2004b; Stephan 2006; Sumell et al. 2006). They argue that by tracking PhDs, we can also track innovations in a way that is not possible through traditional measures of innovations, like patents and R&D expenditures. Next we focus on what we know about the geographical mobility of PhDs. The most important contributors to this literature have thus been Stephan and her co-authors (Stephan et al. 2004a, 2004b; Stephan 2006; and Sumell et al. 2006). Their studies are carried out using the same data source as mentioned above. As a consequence, the results are specific to the Unites States, and focus on PhDs that have recently graduated. Nevertheless, we can see some general patterns in the mobility of PhDs.

Mobility within national borders

When Stephan et al. (2004b) compared regional PhD production, industrial placements of PhDs and industrial and university R&D expenditures several interesting patterns emerged. Firstly, the production of PhDs was geographically concentrated to certain US regions, especially the northeast and the southwest. A similar, but slightly different, pattern was revealed when studying the PhDs hired by the private sector, and especially top 200 R&D firms. It became evident that there were some significant in- and outflows of PhDs between regions. In fact, 63.3 percent of the S&E PhDs going to the private sector moved to another state after graduation (Stephan et al. 2004b). Sumell et al. (2006) pointed out that some regions are net importers of PhDs, while there is a substantial brain drain in others. This suggests that some areas fail to take advantage of the economic advantages that come from PhDs produced in the region.

Stephan et al. (2004b) also showed that the geographical distribution of both university and industrial R&D expenditures differs from the placement of PhDs in the private sector. Industrial R&D expenditures are often used as a measure of innovations. In recent years it has, however, been argued that the systems of innovations have changed and that R&D no longer fully can reflect the innovative processes in the private sector (Stephan 2002; Mowery 1999). As pointed to earlier, Stephan (2002) has argued that human resource data, such as the industrial placements of PhDs, can be used as a complement. The finding of Stephan et al. (2004b) supports Stephan's argument that PhD deployment data can be successfully used to track innovations.

Firms are not very likely to employ locally educated PhDs. It was found that 75 percent of the new industrial hires in the top 25 metropolitan statistical areas (MSA) were from another MSA area. The reasons for this are many. Stephan et al. (2004b) list, among other things the insufficiency of the local labour supply, the employer's wish to diversify the knowledge base and the establishment of networks. Despite this quite pessimistic picture, the role of geographic proximity was found to be important in some regions.

The educational level seems to increase a person's propensity to move. Using the National Science Foundation's data, Sumell et al. (2006) find that the S&E PhDs' in-state stay rates are low compared to those of S&E Bachelor and Master Degree holders. Of the S&E PhDs 36.7 percent reported that they would stay in state. The corresponding percentages for S&E Bachelors and Masters were 62.0 and 60.2 percent, respectively. In comparison, 57 percent of recent law PhDs planned to stay in state of training (National Association for Law Placement 1998, according to Stephan 2006). There were some disparities between different fields in S&E, though. PhDs in agriculture (25%) had the lowest stay in-state rates of all S&E fields, while astronomers were most likely to stay (56%). For engineers, the corresponding share was 36 percent.

Sumell, Stephan and Adams (2006) made an attempt to investigate the specific factors that affect the PhDs' probability of staying in the state of training. They found that graduates in agriculture, engineering, chemistry and computer science are most likely to leave the state. Demographic variables positively affecting mobility are the PhD being Asian or from an underrepresented minority. The same concerns temporary residents. Gender, marital status or the presence of children have no effect on the likelihood to stay local. However, married women

are more likely to stay local than unmarried women. Previous mobility of the PhD affects the probability of staying in the state of training so that PhDs who changed state between college and graduate school are more likely to move also after graduation. The same holds for individuals whose primary financial support was a fellowship or a dissertation grant, and for individuals trained at top-rated programmes in the fields of engineering, biology, chemistry and medicine. Part- or full-time work during the last year of graduate school increased the likelihood of staying local. As far as the attributes of the local area are concerned, Sumell et al. find that individuals from innovative areas, here defined as areas with high counts of utility patents as well as high industrial and academic R&D expenditures, are more likely to stay local. Furthermore, the local labour market's ability to absorb PhDs and the area's per capita income are both positively correlated with the likelihood of staying.

International mobility

As far as international mobility of PhDs is concerned, the literature on brain drain should not be overlooked. Brain drain is often explained as international migration of highly educated or skilled individuals, and emigration flows from poorer to wealthier regions in particular. Brain drain is seen as a problem as it could slow down economic growth. Unfortunately, the highly educated are often vaguely defined in the studies existing in this particular field, sometimes simply as holders of a tertiary education degree. Consequently, distinguishing PhDs especially according to employment sector is troublesome. Saint-Paul (2004) studied emigration from Europe to the USA in the time period 1990-2000, and found that the European expatriates are more highly educated than the population in the home country and that the fraction of PhDs is clearly higher among the expatriates (up to 6%) than among the US population (approximately 1%). Estimations of the magnitude of the brain drain effect vary with approach. Tritah (2008) found that the outflow of human capital from Europe (to abroad, not only to the USA) represents 0.2-0.6% of the total human capital on decennial level, and that the outflow increases when moving up the educational ladder. Saint-Paul argues that if we assume quality heterogeneity among the European PhDs in the USA, similar to the star scientist approach of Zucker and co-authors, then the outflow is much more severe. If the 'stars' make up for 5% of all the PhDs, he claims that as many as 40-80% of the European stars are active in the USA.

What can we say to conclude the literature on the geographical mobility of PhDs? The mobility of S&E PhDs is high, with only 36.7 percent staying local upon graduation (in the USA), but there are great variations between fields and regions. Innovative and wealthy regions with good work opportunities for PhDs have a higher concentration of PhDs. Individuals from top-

rated programmes are more likely to move. Most likely to stay are white individuals with little debt, who are returning to a former local employer. US experience also suggests that regions manage to capture the benefits of PhDs, but not to any large extent, and that the regional variance is substantial. As the geographical mobility is so closely related to the country or region where the research is performed, the importance of national studies should be stressed. Also, mobility between countries should be looked into more closely.

3.4 Conclusions from the international literature

Earlier in this review, we have concluded that there are substantial potential benefits to be gained by the private sector from employing PhDs. On the one hand, benefits accrue to the employing firm through R&D activities and, ultimately, productivity growth. On the other hand, these firm-level effects can spill over to the regional and national level. In view of these implications, the private sector should be an important employer of PhDs. In the USA, the private sector is a relatively important employer of at least S&E PhDs. Stephan et al. (2004b) have shown that among the more than 22,000 PhDs who graduated in 1997-1999, 37% had plans to work in the private sector, even if only 15% could name a firm. They also showed that approximately three times as many PhDs end up in the private sector compared to those who plan to do so upon graduation.

We have reviewed the available international literature, and the overall conclusion is that it leaves a lot to wish for. Information on personal characteristics, like age at graduation and gender, of the PhDs is not available. Most of the existing literature focuses only on the PhDs in the fields of science and engineering, motivated by their contribution to innovative processes. This delimitation is, however, not always desirable, not least because it provides only a partial picture leaving out a considerable number of PhDs and the potential economic benefits they contribute to. In countries where postgraduate education is publicly financed policymakers constantly have to evaluate the system and draw new lines for development, including the number of PhDs that should be educated in respective fields of study. These decisions should to a large extent be taken based on data on the labour market situation of the PhDs. In this context, it is not sufficient to survey only science and engineering PhDs, but all PhDs should be included and, moreover, they should also be followed up during their career.

The literature on career mobility is quite scarce in the sense that the focus of undertaken research differs from our focus of interest. PhD flows between sectors of employment should be studied more closely. Of course, one necessary condition for this kind of study is access to employment history data of the PhDs. If such data is acquired, many interesting questions can be answered. Firstly, the mobility should be analysed in order to display whether or not there are any apparent mobility patterns discernible in the careers of PhDs. Mobility between employment sectors, employers and departments are all dimensions that should all be studied separately. Are there any visible career patterns, and what do they look like? In what career stage do these changes take place? Who are the PhDs who move? Which variables affect most strongly the decision to move?

Secondly, in addition to studying patterns of mobility, it would be important to explore the effects of mobility on the wage profiles of the PhDs. As pointed out earlier, many PhDs begin their careers in postdoctoral and other similar positions. These jobs are typically poorly paid, but they work as important stepping stones into better jobs. By using data on work tasks, we could identify career patterns and hopefully distinguish increased conformity between educational level, field and work assignments. Similarly, we could see how career development is accompanied with increasing wages. Unfortunately, this is a more or less unresearched area thus far. As far as the work assignment question is concerned, the scarcity of empirical studies is probably due to lack of data. That there are no empirical studies of the wage profiles of PhDs is more difficult to explain.

In recent years, the importance of mapping the careers of PhDs has been recognized and understood internationally. In 2002, the OECD secretariat explored the potential of doctorate surveys and started an inventory of national surveys. They concluded that there were national-level surveys, but that these were not comparable. As a result, OECD, in collaboration with Eurostat and UNESCO Institute for Statistics, launched a project with the objective to develop an internationally comparable survey with the aim to study the careers and mobility of doctorate holders. In 2007 the OECD, within the frames of the ‘Careers of Doctorate Holders’ (CDH) project, published guidelines and a model questionnaire formed to study the demographic, employment, mobility and career and salary characteristics of doctorate holders at national and international level (Auriol, Felix and Fernandez-Polcuch 2007). The questionnaire has broad coverage, and allows the answering of many questions of interest. The authors stress the following questions. What roles do PhDs play in the innovation process compared to other tertiary degree holders? Is

there under- or overproduction of PhDs? Is the allocation of PhDs in the labour market efficient? How mobile are PhDs, between countries and sectors? The extensiveness of the survey, and the fact that it allows us to compare many countries, makes it very valuable. A special feature that makes the survey interesting is that for the first time it enables studies of the international mobility of PhDs. The aim of the project is, as already mentioned, to study PhDs in all employment sectors. Since the survey has not been realized yet, however, it is hard to say how well this could be done. The extensive data gathered by means of the survey should enable a close study of the PhDs in the private sector. In connection with the guidelines, a comparison of data from seven countries was published as a pilot study (Auriol 2007). For some reason not named, the pilot study did not comprise the PhDs in the private sector, and therefore the results from it are not reproduced here. The aim of the project is, however, that all PhDs irrespective of employment sector will be included in the future. The framework of the CDH project seems very promising and we look forward to seeing further results from it.

In a volume edited by Merrill and McGeary (Using Human Resource… 2002), the conclusions of a workshop on the theme how to track innovations using human resource data, are summarized. The main contribution of this workshop was that it revised all the available databases containing information concerning science and engineering PhDs in the USA. It analysed the available data, and suggested improvements to be made. Among other things, it suggested how existing databases should be improved, how these could be linked to access new data and what new data need to be collected. The results from this workshop can be used as guidelines for future research. This far, the only attempt to make use of these results has been made by Stephan (2006). Above we have reviewed some of her results.

4 Doctorate holders in Finland

Now that we have reviewed the international literature on the labour market placements of doctorate holders, we will switch focus. In this section, we will study the labour market situation of PhDs in Finland exclusively. We begin by summarizing the situation for all PhDs, irrespective of employment sector, to get a general overview. Then we shift the focus to the PhDs in the private sector. Eventually, we sum up the current situation and give some suggestions for further research.

The knowledge of the placement of PhDs in the Finnish labour market is restricted mainly to surveys conducted by the universities and addressed to (their) recently graduated PhDs. The disadvantage of these studies is that they usually comprise no more than a few hundred individuals. There are, however, two exceptions to this literature. In spring 2008 Haapakorpi published a survey directed at all PhDs who graduated from 11 out of the 20 universities in Finland in 2004-2005. The aim of the study was to examine the doctorate holders' early careers and to look into the value of the PhD degree in the labour market. The study provides a snapshot of the labour market situation 2-3 years after graduation (in 2007). A total of 2,060 PhDs graduated in this two-year period and the response rate was 64 %.

Another study of interest is an article written by Husso (2005b). It surveys the labour market placement of Finnish PhDs in the 1990's using register data from Statistics Finland. Rather than using the term 'private sector' to identify employment sector, Husso uses the term 'firms', in which he includes all firms, both private and state owned. The data might be regarded as obsolete, but it has a few benefits compared to the Haapakorpi study. Firstly, it covers all PhDs, not only newly graduated and, secondly, the longitudinal dimension of the study allows him to identify changes in the placements over time. Thirdly, Husso studies the PhDs in the private sector more closely than Haapakorpi does.

4.1 PhDs in Finland – an overview

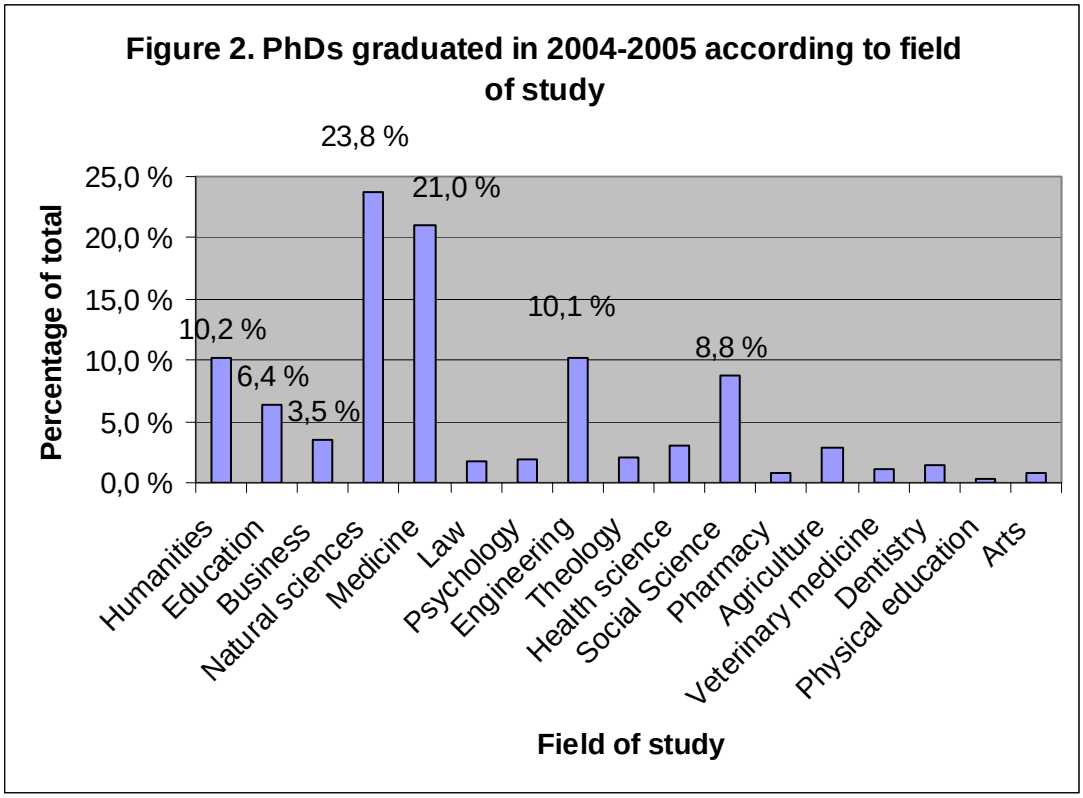
As shown in the outline (Figure 1), the number of doctorate holders in Finland has increased rapidly since the foundation of doctoral programmes in the mid 1990's. In 1995, 765 PhDs graduated from Finnish universities. Twelve years later, in 2007, the number was 1,524. The total number of PhDs in the labour market increased from 11,152 in the end of 1999 (Husso 2005b) to 19,409 in 2005 (Statistics Finland 2007b). The share of female PhD graduates has increased rapidly, up to 50.5% in 2007 (The KOTA database). In the period 1989-2001 the number of doctoral dissertations completed by females increased by 300%, while the increase for males was 150% (Tohtorien työllistyminen… 2003).

Table 3. Stock of PhDs in the population 2000 and 2005.

Field of study	Year			
	2000		2005	
	Total (%)	Females (%)	Total (%)	Females (%)
All fields	14111 (100)	4375 (100)	19409 (100)	7047 (100)
Natural Sciences	3167 (22,4)	868 (19,8)	4250 (21,9)	1357 (19,3)
Engineering	1813 (12,8)	205 (4,7)	2709 (14,0)	409 (5,8)
Medicine and Health Sciences	4671 (33,1)	1795 (41,0)	5983 (30,8)	2709 (38,4)
Agronomy and Forestry Sciences	512 (3,6)	183 (4,2)	687 (3,5)	262 (3,7)
Social Sciences	2449 (17,4)	791 (18,1)	3715 (19,1)	1454 (20,6)
Humanities	1499 (10,6)	533 (12,2)	2065 (10,6)	856 (12,1)

Source: Statistics Finland 2007b.

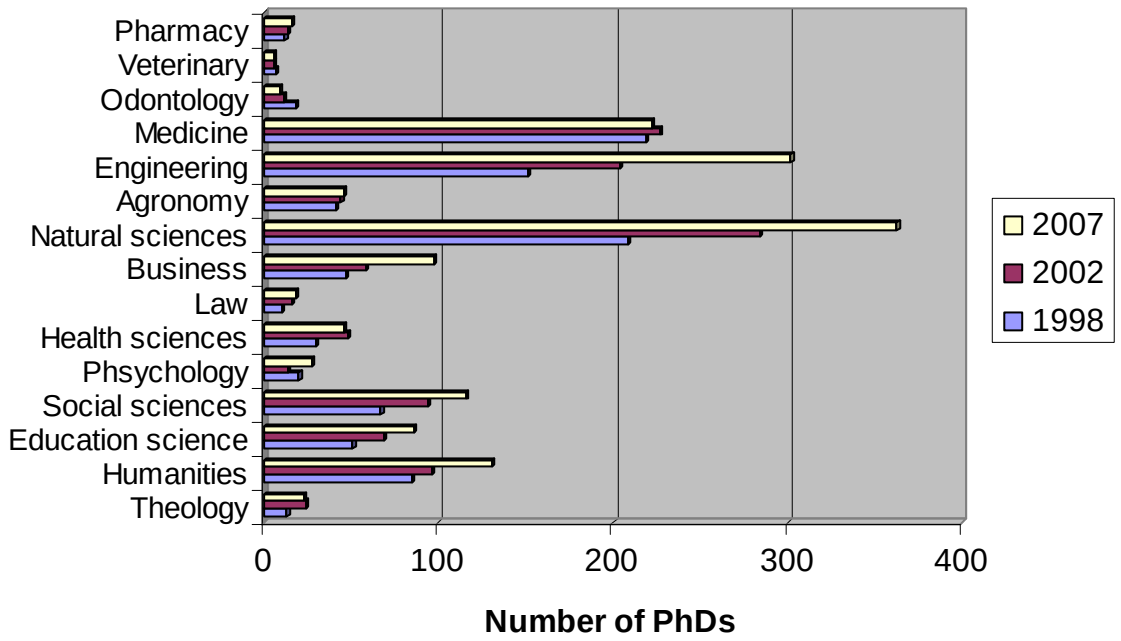
When sorting the 2,060 PhDs who graduated in 2004-2005 by field of study (Figure 2), we see that the most common fields were natural sciences (23.8%), medical sciences (21.0%), humanities (10.2%), technology (10.1%) and social sciences (8.8%). All the other fields had a percentage share smaller than 7% (Haapakorpi 2008).



Source: Haapakorpi 2008 (Derived from table 1 A in the appendix)

A slightly different picture is revealed when studying data from the KOTA Database that includes all PhDs who graduated in 1998, 2002 and 2007 according to field of study (Figure 3). The total number of PhD graduates each year was 980, 1,209 and 1,508, respectively. The primary difference is that the survey by Haapakorpi seems to underestimate the share of PhDs in engineering, probably because of the selection of universities in the study. This is a notable shortcoming of the Haapakorpi study, especially if one is interested in the PhDs who are in the private sector and who often are engineers (see section 4.2). Figure 3 also shows that in most fields the number of graduating PhDs has increased since 1998. The numbers of PhDs in engineering and natural sciences have increased the fastest.

Figure 3. PhDs graduated 1998, 2002 and 2007 according to field of study



Source: The KOTA Database.

Working alongside the doctoral studies is very common. According to Statistics Finland (Oppilaitostilastot… 2008), 13,562 of the 17,727 doctoral students in 2005 worked on the side of their studies. That equals 76.5% which is one of the highest percentages when comparing different levels of education. Male doctoral students (78.9%) worked slightly more often than females (74.4%). Working on the side of the doctoral studies promises well for the probability

of being employed after graduation. Doctoral students who worked alongside their studies often continue with the same tasks after graduation (Haapakorpi 2008) and are thus less likely to suffer from unemployment upon graduation.

Table 4. PhDs according to employment status in 2005.

	In total	Number in the labour force	Percentage	Number of employed	Percentage
All fields	19409	16509	85,1	16121	83,1
Natural Sciences	4250	3567	83,9	3449	81,2
Engineering	2709	2426	89,6	2399	88,6
Medicine and Health Sciences	5983	5096	85,2	5046	84,3
Agronomy and Forestry Sciences	687	563	82,0	543	79,0
Social Sciences	3715	3201	86,2	3105	83,6
Humanities	2065	1656	80,2	1579	76,5

	Number of unemployed	Percentage	Number outside the work force	Percentage
All fields	388	2,0	2900	14,9
Natural Sciences	118	2,8	683	16,1
Engineering	27	1,0	283	10,4
Medicine and Health Sciences	50	0,8	887	14,8
Agronomy and Forestry Sciences	20	2,9	124	18,0
Social Sciences	96	2,6	514	13,8
Humanities	77	3,7	409	19,8

Source: Statistics Finland 2007b.

The employment situation of the newly graduated PhDs was found to be good. Haapakorpi reports that three years after graduation the unemployment rate was, on average, 3% among the PhDs, a figure that corresponds well to the number computed by Statistics Finland. According to Statistics Finland (2005, 2008), the unemployment rate among PhDs one year after graduation increased from 2.2% in 2002 to 3.2% in 2006. Table 3 shows PhDs according to employment status in 2005. At that time, 388 PhDs were unemployed, which equals 2.4% of all PhDs. The unemployment rate for PhDs was considerably lower than that for the Finnish population as a whole. However, there was some variation within the group of PhDs. The unemployment was relatively higher among humanistic (5%) and natural sciences (4%) doctorates and practically non-existing among doctorates in health sciences and medicine, law and educational sciences. Even if the number of PhDs has risen dramatically, their unemployment has increased only marginally. According to Husso (2005b) the unemployment rate

for PhDs was 1.7-2.3% in the years 1990-1999. The unemployment rate for female PhDs was slightly higher than for male PhDs in the 1990's (The Academy of Finland 2003) and still is. In 2005, 2.3 and 3.6% of the male and female PhDs who graduated in 2004, respectively, were unemployed (Oppilaitostilastot… 2008). This difference in unemployment rates was mainly due to gender differences in the deployment between fields of study.

Table 5. Employed PhDs according to field of activity in 2005

Field of Activity	Total number of PhDs	Percentage share	Number of Female PhDs	Percentage share
All Fields	16121	100,00	6006	100,00
Agriculture, forestry and Fishing	45	0,28	18	0,30
Mining industry	4	0,02	1	0,02
Food processing and textiles	42	0,26	22	0,37
Wood products, pulp and equipment	327	2,03	120	2,00
Metal, machines and equipment	308	1,91	53	0,88
Computers and computer devices	319	1,98	38	0,63
Other manufacturing industry	15	0,09	3	0,05
Electricity, gas and water maintenance	25	0,16	7	0,12
Construction	14	0,09	4	0,07
Trade	235	1,46	91	1,52
Transportation	32	0,20	10	0,17
Telecommunications	13	0,08	4	0,07
Finance and insurance business	79	0,49	12	0,20
Data processing	155	0,96	19	0,32
Business services	531	3,29	166	2,76
Public sector research	1384	8,59	556	9,26
Other research	286	1,77	94	1,57
Universities	6130	38,02	2163	36,01
Other higher education	487	3,02	233	3,88
Other education	657	4,08	293	4,88
Health care	3262	20,23	1466	24,41
Public administration	1084	6,72	389	6,48
Other Fields	462	2,87	142	2,36
Unknown Field	225	1,40	102	1,70

Source: Statistics Finland 2007b.

According to Haapakorpi (2008) the most important employer was the universities, employing 38% of the PhDs. Further, 18% were employed by the municipalities, 13% by the government sector, 15% by the private sector and 3% were self-employed. 61% of the respondents were working with research and education and 16% were employed in the social and health sector (Haapakorpi 2008). These findings are largely in line with those of Husso who

found that in 1999 59% of the PhDs worked in the government sector (including the universities), 21.5% in the municipalities, 15.4% in the private sector and 4% in the private non-profit sector. Statistics Finland (Oppilaitostilastot… 2008), however, presents slightly differing statistics. Out of 1,136 PhDs who graduated in 2004 and were employed in 2005, 55% were employed in the government sector (including the universities), 24.5% in the municipalities and 20.5% were employed in the private sector. The last percentage should be interpreted with caution, as it also includes PhDs in firms in which the government is the majority shareholder as well as PhDs whose sector of employment is not known (the number is not noted). The differing numbers could be interpreted as if there has been some restructuring in the public sector or, alternatively, as if the importance of the public sector might be decreasing in favour of the municipalities, and maybe also the private sector.

Table 5 above shows the total number of employed PhDs according to field of activity in 2005. A substantial part of the PhDs is employed in universities and other public research. Other important fields of activity are health care, education and public administration. When all the PhDs in the private sector are added, they sum up to only 2,144 (16.3%). When studying the female shares, universities are still the most frequent employer, employing more than two thirds of all female PhDs. Health care is the second largest employer of female PhDs in both absolute and relative terms.

4.2 Doctorate holders in the private sector

The private sector employs about 15% of all the Finnish PhDs. In this section, we explore our current knowledge about this group. To begin with, we look into the personal characteristics of the doctorate holders in private sector companies. Thereafter we move on to examining their educational and career background.

Personal characteristics

There is no published information on the average graduation age for PhDs working in the private sector. Yet, Haapakorpi finds a linear relationship between age and employment in the business sector. When dividing the respondents into three age-groups according to age at graduation, she found that those belonging to the younger cohorts were more often employed by companies. In the youngest age cohort, with the graduating PhDs being under 30 years of age, 27% were employed by companies. For the second fragment (30-39 year-olds) the correspond-

ing share was 16%. In the oldest cohort (aged over 40 at the time of graduation), only 10% were working in companies. It is worth noting that most PhD graduates are in the second cohort, and that the youngest cohort is the smallest. Here it is worth noting that the differences between age groups mentioned above may be due to a cohort effect rather than an age effect. As Haapakorpi explained it, the high percentage of young PhDs in the private sector is caused by more young persons graduating in technical sciences, and doctorates in technical sciences, on their turn, tend to work in the private sector more often than PhDs in other fields. Thus, age is maybe not the decisive variable here, but reflects rather the choice of subject of the PhDs.

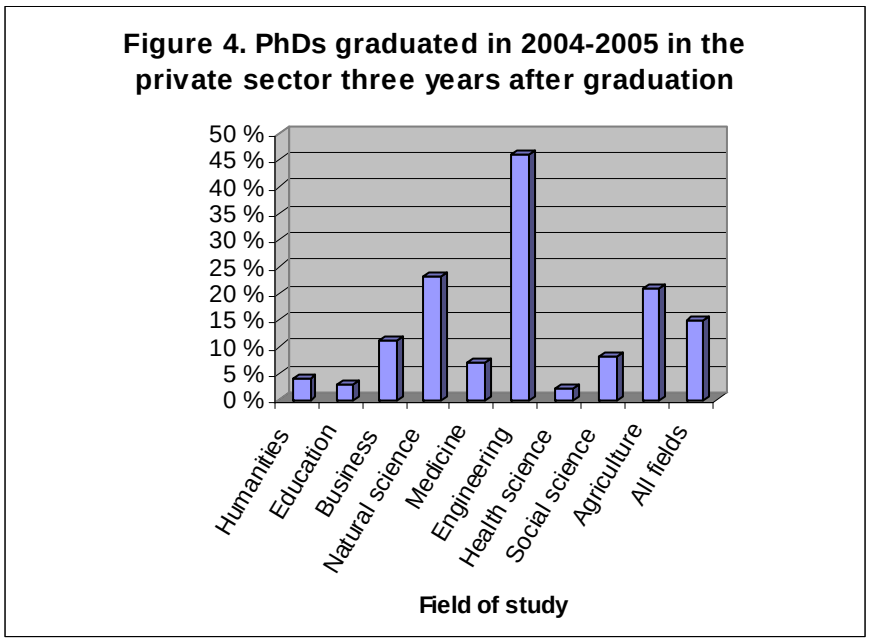
When it comes to gender, Haapakorpi concludes that a larger share of the male PhDs (18%) was employed by the private sector than of the female PhDs (12%). This shows that over all, women work in the private sector less often than men. A noteworthy exception is, however, the slightly larger private-sector share of female than male doctorates in medicine and social sciences. This is offset by the male dominance in natural sciences, though.

Field of study

The field of study of the PhD plays an important role in determining in which sector the PhD will be stationed during his or her career. Haapakorpi finds significant variation in sector deployment between different fields and concludes that PhDs in three fields of study are employed more often by the private sector. These are the fields of engineering (46%), natural sciences (23%) and agronomy and forestry sciences (21%). Husso (2005) finds that one third of the technical doctorates are employed in the private sector, and notes that this number is higher than for any other field of study. The demand for technical doctorates increased drastically in the second half of the 1990's and as many as 44% of the technical PhDs who entered the labour market during this time period were recruited by the private sector. This seems to be in line with Haapakorpi's findings and indicates that an increasing share of the technical PhDs is employed in the private sector.

According to Husso 14.8% of the PhDs in agriculture and forestry sciences and 13.9% of the PhDs in natural sciences were employed in the private sector in 1999. These numbers are lower than the ones obtained by Haapakorpi. The difference might be explained by the different approach of the two studies. Haapakorpi studies the employment situation in 2007 among newly graduated PhDs, and it is possible that these are recruited by the private sector more often than PhDs on average. Of course, the differences in shares can also be due to a change

in the overall behaviour of companies, so that the private sector's relative importance as an employer of PhDs has increased. Also the percentage shares of medicine PhDs in the private sector differs between the two studies. About 14% of the doctorates in medicine are employed in the private sector, and a majority of them are employed in the service sector (energy, construction, trade, transportation, telecommunications, finance, insurance, research, business services, education and health care), according to Husso. For recently graduated PhDs the corresponding percentage is 7% (Haapakorpi 2008), implying that many medicine PhDs start their careers in public health care, only to transit to the private sector later on.



Source: Haapakorpi 2008 (Derived from table 15 in the appendix).

The majority of Finnish private sector firms are members of the Confederation of the Finnish Industries (EK), and so the deployment of PhDs within the member firms of EK reflects the situation in the Finnish private sector quite well, even if the data is not fully representative. In the table below, we see that the number of PhDs in the private sector has quadrupled in nineteen years, from 1985 to 2004, and that the increase has been largest in the last five years of the investigated period. The largest group are the Doctors of Philosophy, who come from a wide range of fields, including natural sciences and humanities. The second largest group are the PhDs in engineering and third are PhDs in health sciences, including PhDs in medicine. The rapid increase in the number of doctorates in the last years indicates that there are ongoing changes in the labour market situation of the PhDs. This increase demands further investigation and stresses the need for recent data.

Table 6. Numbers and percentages of PhDs in the member firms of the Confederation of Finnish Industries (EK)

	1985*	%	1990	%	1996	%
Doctor of Educational Science Doctor of Theology	19	7,98	23	7,12	3	0,87
Doctor of Political Science Doctor of Administrative Science Doctor of Social Sciences	4	1,68	2	0,62	1	0,29
Doctor of Legal Science	2	0,84	1	0,31	0	0,00
Doctor of Business Science	3	1,26	7	2,17	6	1,74
Doctor of Agronomy and Forestry Sciences	11	4,62	11	3,41	7	2,03
Doctor of Philosophy	57	23,95	95	29,41	115	33,33
Doctor of Technology	121	50,84	163	50,46	160	46,38
Doctor of Health Sciences	21	8,82	21	6,50	53	15,36
Doctor in the Service Branch	-		-		-	
Total	238		323	100,00	345	100,00

	1999	%	2001**	%	2004	%
Doctor of Educational Science Doctor of Theology	7	1,46	8	1,39	12	1,29
Doctor of Political Science Doctor of Administrative Science Doctor of Social Sciences	5	1,05	2	0,35	44	4,74
Doctor of Legal Science	1	0,21	0	0,00	6	0,65
Doctor of Business Science	5	1,05	8	1,39	22	2,37
Doctor of Agronomy and Forestry Sciences	11	2,30	13	2,26	29	3,13
Doctor of Philosophy	162	33,89	198	34,43	299	32,22
Doctor of Technology	237	49,58	272	47,30	289	31,14
Doctor of Health Sciences	50	10,46	74	12,87	225	24,25
Doctor in the Service Branch	-		-		2	0,22
Total	478	100,00	575	100,00	928	100,00

* 1985-1990 contain owners and senior management, about 4%.
** 1990-2001 member firms of TT (the predecessor of EK)
Source: The Confederation of the Finnish Industries 2007b.

Career background and mobility

Surprisingly little is known about the careers of Finnish doctorates in the private sector. We know their field of study and some things about how they were deployed within the private sector in 1999 (see section 4.3). The mobility of Finnish PhDs has been studied only once. Husso (2005c) studied the mobility of PhDs, defined as how many PhDs changed employer (both the public and the private sector of employment were included) from the year 1998 to 1999, and also their mobility rates, defined as the share of PhDs who changed employer compared to the total employed PhD work force. In the period of the study 2,100 PhDs changed

employer and the mobility rate was on average about 16%. Mobility within the sectors of employment made up for 32% of total mobility, but the percentage had been decreasing during the 1990's. The increased inter-sector mobility points towards better diffusion of knowledge between sectors. The university sector was the largest employer of PhDs, and it was also the sector with the most mobility. The mobility within the business sector (private and state owned firms) was the third highest after the universities and the municipalities. Of the PhDs in the business sector who changed employer, 49% stayed in the sector. When comparing the in- and outflows of the sectors, the number of PhDs grew the most in the business sector, with a net inflow of 156 PhDs (Husso 2005c).

When studying mobility at the workplace level in the 1990's, Husso (2002 cited in Suomen tieteen… 2003) found that up to one out of four PhDs changed workplace (within or between organizations) each year. In 1999, 33 percent of the PhDs in the private sector changed workplace compared to 18 and 10 percent in the universities and government research institutes respectively (Husso 2002). He also found that the mobility increases with the educational level, so that PhDs are more mobile than other university degree holders.

Husso (2005c) also studied how the business cycle and various background characteristics of the PhDs and their employers affect mobility. The business cycle strongly affected the mobility of PhDs in the 1990's, so that the mobility was at its lowest during the recession, when the unemployment rates were the highest. Their mobility increased again as the economic situation improved. The mobility lagged, however, with one year. Among all sectors of employment, the inflow to the private sector was among the largest (25-43%). Within the private sector mobility varied strongly across industries, and the size of the personnel was found to have a strong negative effect on PhD mobility. Mobility tended to decrease with age, and women were noted to be more mobile than men. This might be due to the fact that many women are on maternity leave at some stage in their careers, which causes them to switch employers more often. Mobility also varied strongly with the field of study. PhDs in medicine and social sciences were the most mobile ones (32 and 27%, respectively), while PhDs in engineering (19%) and agronomy and forestry (21%) were the least mobile. The study of Husso (2005c) provided no information on the direction of the change of jobs, i.e. if the PhDs moved to more, less or equally demanding positions, or on the wage effects of these changes.

Indeed, few studies have examined career advancement through changes in the wage profile. On the whole, the information on the wage development of PhDs is scarce. Here we point out the fine line between studying wages in an attempt to map out the labour market situation of PhDs on the one hand, and estimating the private returns to doctoral education on the other, with the latter aspect being of less interest in this context. Instead, our focus is more on the wages of PhDs from different fields of study and with different job assignments. Haapakorpi (2008) studied the gross monthly earnings of PhDs from different fields, but not according to sector of employment (see table 7). The average gross monthly earnings for PhDs three years after graduation was 3.692,81 € and the standard deviation 1.370,45 €. The highest wages were earned by PhDs in medicine and engineering, while PhDs in the humanities and natural sciences earned the least. Male PhDs earned on average 380 € more than their female colleagues.

Table 7. Monthly gross earnings in year 2007of PhDs graduated in 2004-2005 according to field of study. Mean and standard deviation in Euros.

	Average monthly gross wages	Standard deviation	Observations
Humanities	3072,65	1111,16	106
Educational Science	3803,22	1185,16	69
Business	3811,9	1372,05	39
Natural Sciences	3123,97	807,54	234
Medicine	4533,88	1608,75	207
Engineering	3995,2	1113,49	86
Health Sciences	3788,14	715,68	35
Social Sciences	3517,23	1602,44	88
Agronomy and Forestry Sciences	3482,24	833,81	37
All Fields	3692,81	1370,45	901

Source: Haapakorpi 2008. Table19.

4.3 The private sector as an employer

When mapping out the situation of the PhDs employed in the business sector, it is just as important to find out as much as possible about the demand side, that is, about the employers. Of primary interest is the industry in which the company is active. Moreover, more elementary information such as the size, age, location and R&D expenses of the company can help to shed further light on the demand-side situation. Thereto, the work tasks offered to the PhDs are also of interest. It is particularly interesting to study how these tasks change as the PhDs'

careers progress to see to what extent there is convergence towards an improved match between their education and work tasks.

PhDs in the private sector

As noted in the previous section, about 15% of the recently graduated PhDs in Haapakorpi's study were employed in the business sector three years after graduation. The private sector was thus the third most frequent employer, after the universities and the municipalities. This number coincides quite well with Husso's (2005b) number from 1999. He found that of the nearly 11,000 PhDs in the Finnish labour market in 1999 15.4% were employed in the private sector. This implies that the importance of the private sector has not changed in the last tem years. Of the PhDs in the private sector, 34% worked in manufacturing and 64% in the service sector (Husso 2005b). When comparing recently graduated PhDs with older ones, Husso found that new PhDs more often end up in the private sector and within the private sector more often in manufacturing than in the service sector. The high-tech industry employed over half of all PhDs in manufacturing. Most PhDs were employed in pharmaceuticals (employing 114 PhDs), telecommunications (100 PhDs) and mechanical engineering (84 PhDs). When comparing the results of Husso with those in Table 4 (section 4.1) there are some notable disparities. Statistics Finland reported for 2005 that the most important branches in manufacturing were wood products, metals and computers, each employing more than 300 PhDs. From this it is evident that there have been clear-cut changes in PhD employment during the last few years and these changes would definitely deserve to be more closely studied. The largest service sector employers were business services and health care (300 PhDs each), followed by research services (just over 100 PhDs). When looking at the number of PhDs compared to the total personnel, research services were the most PhD-intense branch (6.5%). In manufacturing, pharmaceuticals were the most PhD-intensive branch (2.0%). In the private sector as a whole, the PhDs constituted only 0.1% of the entire personnel, though.

During the 1990's the PhD relationship between the different sectors of employment did not change much. In the earlier half of the decade, the importance of the private sector decreased as a consequence of the deep recession in the Finnish economy. In the second half, however, there was a rapid increase in the employment of PhDs in the private sector (+57%), and especially in the service sector (+66%). It is worth noting that even if the relative role of the private sector as an employer of PhDs did not change, there was a substantial increase in the absolute number of employed PhDs especially in the period 1995-1999 (Husso 2005b).

Working tasks of the PhDs

Besides studying in what kinds of firms the PhDs work, it is essential also to examine what they do in these firms. As PhDs are fit for working in R&D, a substantial part of them can be supposed to work with such assignments. But, as we will see, surprisingly few of them work with industrial R&D.

Husso (2005b) studied the PhDs in the R&D work force. In the 1990's the Finnish R&D work force grew by 40 percent, to 73,000 employees. This equalled 3 percent of the total work force, which was the largest percentage share in the OECD countries. The growth was fastest in the private sector (+58%). Of the Finnish R&D work force, however, only 11% were holders of a PhD degree in 2002. In the same year, 32% of the R&D work force worked in universities, 15% in other parts of the public sector and 54% in the private sector. The allocation of the PhDs in R&D was, however, quite the opposite. Of the PhDs in R&D, 66% worked in the university sector, 20% elsewhere in the public sector, and only 14% in the private sector. The PhDs in the private sector made up only about 3% of the total private-sector R&D work force (Suomen tieteen… 2003). The number of doctorate holders in private-sector R&D increased with 140% in the 1990's but yet, their share of the sector's total R&D work force did not increase remarkably. This was because the size of the R&D personnel with other degrees increased simultaneously (Husso 2005b). Of the R&D PhDs in the private sector only 22% were women in 2004. This was a clearly smaller share than in the government (state and municipalities; 35%) and the university sector (34%) (Tutkijanuratyöryhmän… 2006).

It is thus clear that PhDs in the private sector are often employed in other tasks than R&D. Of these, however, we have no knowledge so far. Haapakorpi (2008) studied the occupations of PhDs, but only by field of study, not by sector of employment. However, she found that "researcher" was the most common occupation (38%), followed by teacher (21%) and customer and client services (15%). Other, less common positions were managers (8%) and experts (4%). PhDs in the fields of humanities, natural sciences, engineering and agriculture were more often researchers while business, educational and health sciences PhDs were most commonly teachers. Medicine PhDs were most often doctors, while the social sciences PhDs held a wide range of positions.

Firm characteristics

The characteristics of the firms that employ PhDs have not been studied up to this date. The only available contribution in this area is in Husso (2005a). He found that in 1999 small businesses (0-9 employees) employed most PhDs (397 out of the survey sample of 1,694 PhDs). Husso does not specify whether these are entrepreneurs or paid employees. He also found that as firm size increases, the average number of PhDs employed in the firm increases, but not the PhD intensity. Firms with 0-9 employees have on average 1.1 PhDs, while firms with more than 2,000 employees have about 10 PhDs employed on average. Overlooking firm size, the average firm employs 2 PhDs. Once again it is striking how few PhDs there are in the private sector. In comparison with 1995, the number of PhDs in firms and the number of firms employing PhDs had by 1999 increased almost equally fast (56% and 49%, respectively). This fast increase is indeed a promising development, but we have to remember that this happened 10 years ago. The importance of getting more recent data is obvious.

Table 8. PhDs employed in firms and firms employing PhDs in 1995 and 1999.

	1995				1999			
Size of the firm	Number of PhDs	Percentage share	Number of firms	Percentage share	Number of PhDs	Percentage share	Number of firms	Percentage share
0 - 9	282	26,14	257	45,65	397	23,44	361	43,08
10-49	161	14,92	119	21,14	303	17,89	210	25,06
50-249	130	12,05	74	13,14	249	14,70	123	14,68
250-499	93	8,62	29	5,15	108	6,38	42	5,01
500-1999	228	21,13	56	9,95	324	19,13	70	8,35
2000-	184	17,05	23	4,09	307	18,12	31	3,70
Unknown	1	0,09	5	0,89	6	0,35	1	0,12
Total	1079	100,00	563	100,00	1694	100,00	838	100,00

Source: Husso 2005a. (Table 2)

4.4 Summary of the situation in Finland

The information we have on PhDs in the Finnish private sector is in every aspect very scarce, and there is a striking need for further research to fill in the information gaps that are so evident today. What we know this far is that about 15% of the PhDs are employed in the private sector. Being younger and male increases the probability of being employed in the private sector. The differences between fields of study are, however, large with more than 20% of

PhDs in natural science and engineering employed in the private sector compared to less than 5% of the PhDs in humanities and educational science. Depending on the time and way of measuring, the mobility among PhDs in the private sector varies. However, PhDs within the private sector are among the most mobile in the labour market. Within the private sector, the manufacturing sector employs about one third and the service sector two thirds of the PhDs. The top hiring industries were pharmaceuticals and telecommunications in manufacturing and business and health services in the service sector. When Husso (2005b) studies the PhDs in the R&D work force, he found some interesting patterns. In 2002, the Finnish R&D work force made up over three percent on the total work force and this was also the highest share among the OECD countries. 54% of the R&D workforce was employed in the private sector. However, of the doctorate holders in R&D jobs only 14% were employed in the private sector. Thus, there seems to be relatively less PhDs in private R&D compared to the other sectors of employment. Most PhDs are employed in small firms with less than 10 employees. However, the distribution of PhDs between firms of different sizes became more even in the 1990's. corresponding information for the 2000's is not available.

5 Conclusions and prospects for future studies

We can easily put forward at least three reasons for studying PhDs in the private sector. First, and most generally, the doctoral education is often to a large extent financed publicly and consequently it lies in the interest of the society to obtain information about the societal returns on this very costly investment. Second, PhDs are often assumed to contribute to economic development, especially through working with research and development in the private sector. Therefore keeping an eye on the PhDs might help us understand and manage economic development. Third, the fact that we know very little about the PhDs is in itself a good motivator for studying them more closely. All these reasons served as starting points for this review, in which we have tried to map out what we know about PhDs in the private sector up to this day.

The main findings of this review have already been summarized and discussed at the end of respective section but to sum up we will shortly repeat them here. Firstly, we have seen that there are several ways in which private-sector firms can benefit from employing PhDs. Be-

cause of their special skills PhDs are suitable for working in R&D activities. Tacit knowledge makes the PhDs particularly valuable for the private sector since this kind of knowledge is difficult to get possession of. Apart from working in R&D, PhDs are often part of inter-organizational networks, through which they bring new knowledge to the firm. The positive impacts of PhDs can be measured in terms of productivity growth and increased innovative activities. Up to this date, we lack exact knowledge of these effects, but empirical studies do suggest that there are positive productivity effects of highly educated labour (Maliranta and Asplund 2007). All in all, we can conclude that there seem to be clear-cut benefits accruing to firms that employ PhDs. As a next step we explored to what extent the private sector makes use of PhDs.

In order to map the utilization of PhDs in firms, we have studied the deployment of doctorate holders in the private sector. We have found that the private sector is not as important an employer of PhDs as one might expect. In Finland only 15 percent of the PhDs work in the private sector. There are, however, clear disparities between fields of study, with PhD engineers being the ones most often employed in the private sector. In the USA, the percentage of PhDs working in the private sector seems to be larger, but it is not fully comparable to the Finnish number since the available information covers PhDs in science and engineering only. It is also worth stressing that the information available for Finland refers mainly to the labour market situation of PhDs in the late 1990's; and the fast economic and technological progress in the 2000's suggests that the labour market situation of PhDs in the private sector might have changed since then.

Hence, there is some available research on the employment situation of PhDs, but it has its shortcomings. To begin with, the literature on this subject is quite inadequate. We have seen that only very few studies focus on the PhDs in the private sector. Often, however, the biggest problem is not scarcity of information, but the shifting focus of the available studies. For example, one strand of the literature focuses on science and engineering PhDs only while another strand deals with star scientists. Furthermore, some studies do not particularly distinguish PhDs but treat all university degree holders as one group. Moreover, empirically the focus of study has often been all PhDs irrespective of employment sector or even PhDs in the university sector only. Thus, the problem is not always complete lack of information, but rather that the available research does not answer the questions we have raised, and additionally, that the varying focus makes comparisons of the studies more difficult.

Yet another drawback of the existing studies is that most of them are surveys based on questionnaires directed to recently graduated PhDs. These surveys tend to understate the number of graduating PhDs going to the private sector as many more PhDs typically end up in the private sector compared to those who initially plan to do so. Thereto, due to their structure, surveys seldom provide possibilities to follow up the PhDs over time. One solution to this problem would be to use register-based data rather than surveys. The advantages of register data are obvious. Good register data contain all PhDs irrespective of field of study and time of graduation. It also allows PhDs to be tracked over time. It goes without saying that surveys are not useless. The advantage of a survey is that it is not restricted to the kind of data available in registers, but can cover a whole set of questions to which we wish to have answers.

In Finland we have access to comprehensive registers from which data on PhDs in the private sector can be derived. For this purpose especially two registers are helpful. The Confederation of Finnish Industries (EK), collects data on the employees in their member companies every year. At the end of 2007, EK had 16,200 member firms with 930,000 employees in total (Toimintakertomus… 2008). Not all, but a large majority, of all firms in the private sector are members of the Confederation. Some of the smallest firms are not members. It is compulsory for Confederation members to provide data for the Confederation database, so the response rate is nearly 100%. The data covers the manufacturing and the service sector. The manufacturing sector data is available from 1980, separately for workers paid by the hour and white-collar workers. The service sector data is available from 1990 and makes no difference between blue- and white-collar workers (Asplund and Böckerman 2008). In the EK data it is possible to follow the employees of member companies from year to year. The drawback of the data is that we have no information on the employee before he or she enters a member firm. Similarly, we can only follow an employee as long as he or she is employed in a member firm. We have no possibility to follow up individuals leave a member company which means that we have no information on the individual's labour market position (unemployed, working in a non-member firm or in the public sector) when not observed in the EK data.

Another dataset of interest is the Finnish Longitudinal Employer-Employee Data (FLEED) that has been created by Statistics Finland by linking various administrative registers, such as the Business Register of Statistics Finland and the Financial Statements Statistics, and covers for the mombent the years 1988-2004. Basically all individuals between 17 and 70 years of age living in Finland are included. The dataset contains detailed background characteristics

of the individuals as well as comprehensive information on their employers. The fact that the data allows identifying the employment status of the individual and linking this to an employer provides the possibility to study career advancements. Other advantages of FLEED are that it allows tracking of the lifecycles of both individuals and companies and that it is representative for the private sector (Maliranta and Nurmi 2004).

For future research, the first task would be to perform a thorough mapping of the PhDs in the private sector. A comprehensive basic study should preferably be both descriptive and statistically as detailed as possible. First, it should try to identify and compare the PhDs in the private sector through collecting information on a broad set of background characteristics concerning both the individuals themselves and the firms that employ them. Future research should map out which these PhD employing firms are; where they are located geographically, in what branch they are operating, as well as their size, age and R&D expenditure. Furthermore, as the number of PhDs has increased rapidly in recent years, it would be important to study how their labour market situation has changed in this time period.

Only when these issues are investigated can research move on to answer more applied questions. Especially important areas for future research are the mobility of PhDs, both geographical mobility and mobility in terms of career paths. Thus far, the literature on both issues is inadequate.

As far as geographical mobility is concerned, both mobility within and across borders should be studied. A study of the regional placements migration flows of PhDs can, as Stephan (2002) argues, help track national innovation systems. Furthermore, it is relevant for analysis of regional economic development. At present there is an intense discussion on the effects and extent of brain drain on the agenda world wide. A better mapping of the international mobility patterns of PhDs would help understand and evaluate the magnitude of the phenomenon. Data on the mobility of PhDs across borders is not yet available, but as the OECD project Careers of Doctorate Holders (Auriol et al. 2007) is realized, we hope that this situation is improved.

The study of mobility in terms of career development of PhDs is important for several reasons. First, career mobility can be used to study the diffusion of knowledge within the economy. There is a vast strand of literature that has tried to study the ways in which knowledge transfers work. Common approaches have been to study the use of scientific articles and pat-

ents in firms. Studies of the mobility of PhDs between and within sectors can serve as important complements to earlier work on knowledge transfers as well as research in technology and innovation systems. Second, studies of career mobility can shed further light on important policy questions, such as how PhDs make use of their training, if the investment in education of PhDs pays off on a societal level, if there is overproduction of PhDs and if they are efficiently allocated, i.e. how many PhDs should be educated and in which fields. Some effort has been put into answering these questions already, but mobility studies could widen the perspective further.

Third, mobility within and between organizations has been shown to be an important source for wage growth (Topel and Ward 1992; McCue 1996). However, this has not yet been studied explicitly for doctorate holders. As pointed out earlier, many PhDs start their careers with postdoctoral and other similar positions in the university sector. These jobs are typically poorly paid, but they work as important stepping stones to better jobs. According to mobility theory (see e.g. Burdett 1978; Jovanovic 1979; Sicherman and Galor 1990), the mobility to better jobs can be presumed to be accompanied by rising wages. By using data on working tasks, we could identify crucial career advancement patterns and hopefully distinguish improved conformity between educational skills, work assignments and wages.

A first step in studying the career mobility of PhDs would be to map out the mobility flows - and the changes in them over time - within and between employment sectors, employers and departments. The direction, the magnitude and the timing of the mobility flows are all of equal importance in this context. It would be of great interest to see if there are any apparent patterns of mobility, such as varying mobility frequencies and types of jobs in different career stages. Second, research could try to explain the mobility, by use of regression models, as in Husso (2005c). Third, the effects of the mobility of PhDs on their wages but also more generally on the innovative activities of organisations and, ultimately, on economic growth.

Due to the recent rapid increase in the supply of PhDs in the Finnish labour market many questions have arisen concerning their labour market situation. Has the role of the private sector as an employer of PhDs changed and how? Has the increased supply been offset by a corresponding increase in demand? How has the increased demand affected the value of the doctoral degree; that is, are the PhDs rewarded with lower, same or higher wages than earlier? These are all examples of important research questions for future studies. The deployment of

PhDs in the private sector is a convenient field of research in the respect that every piece of information we can get our hands on is valuable. As so little is known thus far, there are still many important questions for researches to answer in this particular field of study. Furthermore, it is a subject that is of great interest to a wide range of actors, such as policymakers and private-sector managers who face up-coming recruitment decisions.

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