DISCUSSION PAPER SERIES

IZA DP No. 3084

Estimating the Need for PhDs in the Academic Sector via a Survey of Employers

Jaan Masso
Raul Eamets
Hanna Kanep

September 2007

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

Estimating the Need for PhDs in the Academic Sector via a Survey of Employers

Jaan Masso
University of Tartu

Raul Eamets
University of Tartu
and IZA

Hanna Kanep
University of Tartu

Discussion Paper No. 3084
September 2007

IZA

P.O. Box 7240
53072 Bonn
Germany

Phone: +49-228-3894-0
Fax: +49-228-3894-180
E-mail: iza@iza.org

IZA Discussion Paper No. 3084
September 2007

ABSTRACT

Estimating the Need for PhDs in the Academic Sector via a Survey of Employers*

The aim of the current paper is to estimate the need for new PhDs in the Estonian academic sector for the 5-year period 2007-2012 using a survey of employers, such as universities, institutions of applied higher education and research institutes. The doctoral workforce in all countries around the world constitutes a rather small segment of the labour market; however, PhDs provide a crucial input for educational and R&D activities not only through their employment in the academic sector, but nowadays also increasingly in the public and private sector. Our results show that academic institutions would prefer to hire a rather high proportion of new PhDs – almost 100% of the current number. On the one hand total demand is high due to a high replacement demand brought on by retirements in the next years as a result of the current unfavourable age structure of the doctoral workforce. Still, the growth demand constitutes more than 50% of the total demand. Such growth, in our view, assumes significant growth in research funding, which the respondents mostly did not believe would occur, despite it having been foreseen in national R&D policy documents. In general, the respondents seemed to see the problem being the lack of PhDs rather than the lack of funding. The policy implication of our results is that the planned increase in the numbers of PhDs should be in accordance with other developments in educational and R&D policy.

JEL Classification: I2, J4, O3

Keywords: PhD, higher education, research and development, academic fields

Corresponding author:

Raul Eamets
University of Tartu
Faculty of Economics and Business Administration
Narva Road 4-124
51009 Tartu
Estonia
E-mail: Raul.Eamets@mtk.ut.ee

* The authors acknowledge financial support from the project “Assurance system for quality, effectiveness and sustainability of doctoral studies in Estonian universities” that is funded by the European Union. We thank the participants of the seminar at the Faculty of Economics and Business Administration at the University of Tartu and the conference “PhDs for the Development of Estonia” at the University of Tartu for their comments. We take sole responsibility for all errors and omissions.

1. Introduction

Both in the aims of the Lisbon strategy and the development plans for EU Member States (including Estonia), the movement towards a knowledge-based and innovative economy is emphasized. Therefore, the role of science in the organization of society is becoming increasingly important. Accordingly, the role of individuals with academic degrees (primarily those with a PhD) in society will start to grow in the future, and it is important to change the stereotypical public opinion that PhDs are exclusively needed in the academic sector to fill professorships. Individuals with academic degrees are needed both in public and private sector institutions that undertake analytical work (including, for instance, economic analysis or the estimation of environmental impacts) because the presence of the doctoral degree assumes a command of the analytical tools of the respective area.

The demand for doctorates[2] originates thus both from the academic, public and private sector. Earlier statistics and studies have shown that most of the graduates of doctoral programmes start working in the academic sector (medical specialists are an exception)[3]. For instance, in the US in 2003, 47% of all doctoral scientists and engineers worked in educational institutions, 31% in the business sector and 16% in central and local government (National Science Foundation, 2003). In other countries, the share of PhDs working in the academic sector is even higher[4]. Proceeding from that, earlier studies have asserted that the most important (and growing) share of the demand for scientists comes from the academic sector and that will be so also in the future (Boddy, 1962). However, more recent studies point out growth in the demand for doctorates in the private sector (Cruz-Castro and Sanz-Menendez, 2005). Similarly, in Estonia most of the doctors engaged in research and development activities (hereinafter also R&D)[5] are employed in the higher education sector (in 2003, 82%). Another 10% were employed in the state sector, 6% in business and 1% in the non-profit

[2] Doctorates can be considered those with an advanced research degree corresponding to the 6th level of the ISCED classification used to classify curricula and educational levels internationally.
[3] Often the academic sector has been classified under the public sector, similarly most medical workers belong to the public sector (local governments).
[4] For instance, in Finland 80% of the graduates of doctoral programmes found jobs in the public sector, 4% worked in the private non-profit sector and 15% in private business (PhDs in Finland…2003). In Canada, in 2001, among science and engineering PhDs, 57% worked in the public sector and 43% in the private sector (McKenzie 2007).
[5] This figure includes those who spend at least 10% of their working time on research and development activities.

private sector. That is also reflected in the survey of Estonian PhD students where 74% of respondents indicated that "Orientation towards an academic career" was a reason for starting doctoral studies; perhaps as expected, that reason was more important in the humanities and less important in the technical sciences (Puura *et al*, 2004). Similarly, most PhD students associated their future career with the academic sector and during their studies already 74% worked either in higher education or research institutions.

Though PhDs are of crucial importance for research and higher education, their exact demand is hard to predict because many factors impacting it (educational and R&D policy decisions, technological changes, etc) are either hard to predict or fundamentally unpredictable. Balancing PhD supply and demand might be complicated due to the long period of time needed to obtain a PhD degree, and this complicates the adoption of supply to meet the demand. A shortage of staff with a doctoral degree may adversely affect the quality of teaching, but even more importantly, the amount and quality of research. Higher teaching loads may reduce research productivity, larger classes may decrease interaction between students and professors, increased retirement ages can also have a negative impact (Basil and Basil, 2006).

We are convinced that based on previous studies the total demand for doctorates can be divided into three basic components – firstly, research and development institutions and higher education institutions, both in the public and private sectors; secondly, the rest of the public sector; and thirdly, the rest of the private sector, which in our context signifies mostly business activities. This paper focuses on the first component[6]. The aim of the current paper is to estimate the need for new PhDs in the academic sector of Estonia, a small country in Eastern Europe with a catching-up economy, over the 5-year period 2007-2012. Our estimations will be based on a survey of employers, such as universities, institutions of applied higher education and research institutes. The demand for PhDs may come either from the necessity to replace faculty leaving due to retirements or other reasons, or the growing level of employment of PhDs. Our contribution to the literature is threefold. First, we aim to evaluate the usefulness of the surveys of employers for predicting the demand for PhDs. While the advantage of such an approach is that the respondents have lots of inside

[6] The work of our research group will continue with the analysis of the PhD demand in the Estonian public sector and in the private sector. The analysis has started with the research and higher education institutions, because the biggest proportion of present and future PhDs are employed in this sector.

information about developments in their sector, the disadvantage of such a survey is very subjective nature of the answers and the answers being dependent on the particular person interviewed. Secondly, the existing studies seem to be exclusively made in highly developed countries and there is not much information on PhDs in developing and transition countries. Eastern-European transition economies face many common challenges, such as the ageing of academic staff in higher education, and need to increase the current low levels of research and development expenditure and restructure their economies in order sustain competitiveness in the context of a vanishing low labour cost advantage. Thirdly, we will estimate whether the targets set in national policy documents for the PhD defences match the actual needs of the academic sector[7].

The rest of the paper is structured as follows. The following section reviews existing literature on the demand for PhDs; here we mostly focus on the need for PhDs in the academic sector. However, we also pay attention to the more general issues of PhD employment. The third section provides background information for the study by presenting the main trends in research and higher education policy in Estonia. The fourth section describes our research methods and data, and the fifth section presents the results. The final section concludes with policy implications.

2. Overview of the literature on the demand for PhDs

Discussions surrounding the future demand for PhD holders and the current and future imbalance of their supply and demand have been around for several decades. Regardless, there is so far no consensus on the appropriate methodological approach to the problem and thus studies employ methods varying from econometric models to interviews, questionnaires and informal discussions of factors affecting the supply and demand of doctorates. Considering the huge variety of fields within the scientific sphere and breadth of the labour market for PhD holders, most of the studies concentrate either on particular fields[8] or a particular part of the labour market – public sector, academic sector or private sector. Due to the high concentration of doctorates in the academic sector, the largest number of studies

[7] The previous expert estimates of the number of doctorates needed in Estonia have claimed that approximately 300 to 350 PhD defences are needed in order to replace leavers and to achieve the necessary growth in the employment of PhDs in academic, public and private sectors. We will attempt to find evidence that either confirms or disproves these numbers.

[8] The most common fields addressed have been economics (Cartter, 1972, Hansen *et al*, 1980), business administration (accounting – Campbell *et al*, 1990; marketing – Basil and Basil, 2006), engineering and science.

deals with that sector. Many studies have also focused more broadly on the category of scientists and engineers or the total staff working on R&D instead of singling out PhDs.

Interest in predicting PhD supply and demand first emerged in the 1950s in the US (Forecasting demand…2000). In fact, almost all papers analyse PhD supply and demand in one country. The concern and motivation for many studies is the possible undersupply of PhDs, and most studies discuss a potential deficit rather than the overproduction of PhD holders. It has been found that the US labour market for doctorates is characterized by huge fluctuations and imbalances of supply and demand. One of the reasons for this could be the long period of time needed to obtain a PhD degree, which complicates take up according to demand; lengthy training periods for PhDs may lead to varying spells of over-supply and undersupply (cob-web)[9]. Concerning the causes for the shortage of doctorates, it is also argued in the literature that the production of PhD's might be a financial loss for schools, thus the situation emerges of the tragedy of commons where they are not interested in producing PhDs (Basil and Basil, 2006). An example of overproduction can be drawn again from the US, where in the 1980s many students started their PhD studies on the basis of prognoses that expected great numbers available academic positions due to retirements. In reality, these developments did not take place and the overproduction resulted in lower wages for new doctorates in the labour market. Another reason for overproduction might be that PhD students frequently create additional value for the faculty and the university by engaging in research and other obligations, so the problem of overproduction is very sensitive because universities often need to have PhD students even if there is not a matching demand in the labour market (Jones, 2002-03). Another factor is that producing PhDs might help stimulate further demand for research (McIver Consulting, 2004). Both under and oversupply might be costly (as we described in the introduction).

However, forecasting in this market is not easy. While some factors are relatively easy to predict (demographic changes), some others, such as future technological changes are quite difficult to predict (Forecasting demand…2000). Given that, Leslie and Oaxaca (1993) summarized that the literature seems to imply that forecasting models are of questionable value in the longer term, and thus it is necessary to understand the factors behind the supply

[9] Braddock (1992) also finds that the supply of doctorates reacts to demand with a certain delay. Several other studies have also suggested that the labour market for scientists and engineers acts as the normal labour market in the sense that when a deficit or overproduction occurs, market forces are able to draw back the system to a near balanced condition (Brown, 1993).

and demand for scientist and engineers. Also, there are no forecasts, but rather projections (predictions conditional on assumptions regarding future economic and labour market conditions). Often, the relative shortage or over-supply is analyzed using indicators like relative wages, vacancies, unemployment rates, field of employment, etc. (Borthwick and Murphy, 1998; PhDs in Finland… 2003).

Due to the characteristics of the academic and business sector, the approaches used to estimate PhD demand differ. In the academic sector, PhD demand results mainly from the retirement of the older generation on the one hand, and on the other hand from future developments in research and higher education financing by the public and private sector (Pauli and Savunen, 2004). One classic paper on PhD demand in the academic sector is the study by Cartter (1966) on the supply and demand of instructors in higher education institutions in the USA. The total number of necessary lecturers can be expressed through the number of students (enrolment) and the inverse of the student-lecturer ratio[10]. His model consisted of the independent forecast of the number of undergraduate students and new doctors, the assumed ratio of students to instructors, the assumed percentage of new teachers with PhD, and the presumable replacement rate to correct for deaths, retirements and movements to other sectors[11]. The main drawback of that approach is that the only determinant of changes in the faculty size is changes in enrolment[12], and other factors like R&D activities are ignored (Shapiro 2001). Another drawback was the focus on full-time PhD holding faculty positions while many faculties were also employing part-time faculty and graduate students as instructors. Later, that approach was also used by Hermanson and Miles (1976) to study the supply and demand of PhDs in accounting. Cartter (1971) studied the demand for academics in economics in the US during 1957–1985 by using analogous factors – demographic developments (changes in size of the age cohort 18-21), the desired percentage of academic staff with a PhD and the need to replace deaths and retirements. The advantage of the study by Hansen *et al* (1980) over previous approaches was the involvement of wages as a

[10] When data is gathered by institutions (not at the aggregate level), both the left and right hand sides of the equation should also include the number of teaching staff who change college during the year. That cancels out when aggregating.

[11] The values of the parameters were taken from previous studies. Some of these, such as the factors impacting the replacement rate, are rather stable, while some others are rather changeable, such as mobility between academia and other sectors (its value depends on the relative wages of academic and non-academic jobs) and the proportion of PhDs (that can be taken as a measure of the quality of the teachers). The forecasts made using that model assumes a constant replacement rate and a constant faculty coefficient (constant quality model) or that a constant percentage of new PhDs will start teaching (absorption model).

[12] Enrolments can be relatively easily forecasted from the age-structure of the population determined from census data.

market adjustment mechanism. The study modelled and forecasted the labour market for doctorate economists in the US by looking at the supply and demand of doctorate economists in the public sector on the one hand and admission and graduation figures on the other. The demand for new PhD holders was set to be dependent on wages, the number of students, national research grants in economics and different national and state level costs (R&D costs, defence costs).

Thus, most studies have distinguished between replacement demand and growth demand. The first includes new PhDs to replace retirements, deaths and net movements between academia and other jobs. The results of different studies have shown that the most significant component of replacement demand results from the need to replace retirements; the demand to replace deaths and net movements between academia and other jobs form a rather modest share (Campbell *et al*, 1990); thus, data about the age structure of PhD holders has been used to study the retirement demand component. The growth demand is equal to the change in the total number of PhDs employed. Growth demand has been assumed to follow past growth demand (Campbell *et al*, 1990), but at the same time should consider demographic factors (e.g. smaller growth of students because of the end of the baby boom generation at the beginning of 90s), employment costs, changes in required student-to-lecturer ratios, pressure on academics to publish more which inevitably leaves less time for teaching and other field-specific factors. Both supply and demand of PhDs are also affected by international mobility; which, however, cancels out at the world level.

It has been stated that one of the major faults of discussions of the demand for PhDs has been the lack of consideration of the backlog of demand. Backlog of demand results when, at some point in time, the shortage of labour force has emerged, meaning that the demand exceeds the supply cumulatively and gaining a balance takes more time. Similarly, there could also be a backlog of supply if the PhDs who could not find employment in the academic sector in previous periods return to the academic labour market (Shapiro 2001).

Although traditionally, the academic sector has been the greatest employer of PhDs, the share in the private sector is growing. In the private sector, PhDs are first of all needed in R&D activities; however, what is important is also the mobility of PhDs between science and industry, and not only their employment level at some point in time[13]. The analyses of PhD holders in the private sector have concentrated on the industry. Bosworth (1981) modelled the demand for qualified scientists and engineers in the UK manufacturing industry by assuming that qualified scientists and engineers are employed in four different functions: 1) production, 2) R&D, 3) installing and testing new technologies, and 4) advertising and marketing. The empirical results showed rather low levels of elasticity of substitution for scientists and engineers on the one hand, and other inputs on the other implying that entrepreneurs face difficulties in replacing scientists and engineers with less qualified labour. The demand for scientists and engineers was expectedly most sensitive to R&D costs. The results from Mace and Taylor's (1975) assessment of the demand for engineers in UK firms via interviews with large companies revealed by contrast that engineers positions were filled by employees with different qualifications and qualified engineers were not necessarily working in positions in accordance with their profession. McIver Consulting (2004) derived estimates for PhD and non PhD R&D employees in Irish businesses from employment figures on the basis of industry, the share of research staff in industry employment, the ratio of PhDs to non-PhDs and the constant annual replacement rate.

In addition to general macro models, methods based on questionnaires and interviews of people in institutions (universities, government agencies, private firms), job candidates, as well as expert opinions have been used to find out the demand for PhD holders (Freeman *et al*, 2000; Shawver, 1973; PhDs in Finland… 2003 etc). The advantage of these methods is their consideration of real situations and future trends since the individuals working in the field routinely have the best insight into the matter. Expert opinions can, however, be at the same time too subjective, be based on untested assumptions or incline towards the expert's favourable direction. In order to avoid this, a consensus of opinions from an expert group (so called Delphi method) has sometimes been used. The forecasts of the demand for qualified scientists and engineers based on interviews with employers have also been criticized for not revealing the reasons behind the decisions made by firms, and the lack of information on the sensitivity of demand within the firms towards changes in economic conditions (Bosworth,

[13] For knowledge and skills to be able to move between the academic and industrial sphere, in addition to scientific publications, datasets and computer programs, people also need to be mobile. Part of the knowledge (so-called tacit knowledge, cf. codified knowledge) is always attached to the individuals through their competences and experience. Therefore, the location and mobility of the competence become very important in analyses of technology transfer, especially between universities and enterprises. (Lanciano-Morandat and Nohara 2004). The positions of PhD holders in firms give vital information about which type of knowledge obtained in universities are applied and which university-industry networks are created (Sumell *et al*, 2005).

1981). Informal analyses of different assumptions have also been used to forecast the demand for PhD holders. Assumptions are made about possible factors affecting employment in fields with a high concentration of scientists and engineers and the factors influencing the share of scientists and engineers in branches of industry (Braddock, 1992).

Another method for analysing demand in the private sector is benchmarking. In that case, a country is chosen to serve as an example that is considered to be the desired target considering future developments, and the respective indexes or employment/graduation coefficients are then projected for the country under observation. The limitation of this approach is that there are no two identical countries.

The volume and the quality of data available for researchers as well as the experience of analysis in this field vary significantly between countries. Most of the studies conducted on the demand for PhD holders originate from the US. The reason for this is the decades of data collection on the subject there including surveys like the *Survey of Earned Doctorates* (SED) and *Survey of Doctorate Recipients* (SDR)[14]. In the UK, the first studies on the demand for scientists and engineers were carried out in 1950s (Godin, 2002), in other countries it was later. Aside from the study of PhD supply and demand, research has also been conducted on the labour market for young scientists (see Recotillet (2003) for databases and research made in Europe on that topic), young scientist entrance into the labour market shortly after graduation (like the "What Do PhDs Do" study in the UK, UK GRAD Programme (2006))[15], the international mobility of highly qualified labour and factors affecting (see Brain Drain – Brain Gain (2002) for Germany; see Auriol (2007) for an international comparison of OECD countries).

The labour-market performance of PhDs in various fields differs as well. Based on the US *National Science Foundation* different aspects in the employment of doctorates of different fields have also been found. For example, in 1999, after 1–3 years of working experience, doctorates of physics, astronomy and mathematics experienced more involuntary inactivity

[14] The first of the two follows the number of PhD students every year and is used as an input for the second, which collects data on different characteristics (employment status and sector, academic position, yearly wages etc) of scientists and engineers with PhD degrees (Cox *et al*, 1998).
[15] In Portugal, a similar study was carried out in 2000, in the UK, the *First Destination Survey*, in Ireland, the *First Destination of Award Recipients in Higher Education*'. Several studies have focused on the academic mobility of the young scientists.

than others. Physics and biology doctorates were most frequently in post-doctorate positions and doctorates of political science had the highest unemployment and inactivity rates (Jones, 2002-03). According to Pauli and Savunen (2004), doctorates in technology, medicine and natural sciences have been the most successful in finding employment in Finland. Various indicators have been used for the comparison of the success of the doctorates of different fields. For example, high numbers of doctorates of discouraged status in the labour market and in post-doctorate positions have been seen as an indication of the difficulty of finding jobs. However, both of these indicators can be interpreted in several subjective ways (Jones, 2002-03).

3. Science policy, higher education policy and PhD employment in Estonia

The total employment of PhDs is certainly connected to total expenditure on research and development[16]. The total R&D spending as a percentage of GDP was 0.94% in Estonia in 2004. With that figure Estonia exceeds the average of the 10 new member states (0.82%), but lags behind the EU average (for EU15 1.91%, for EU25 1.85%). The difference is especially remarkable regarding Estonia's Scandinavian neighbours, Finland and Sweden, who spent respectively 3.5 and 3.8%. National policy documents have set the target for 2014 at the level of 3% (Knowledge Based Estonia 2007–2013). The increase in total R&D spending in recent years (from 0.6% of GDP in 2000 to 0.94% in 2004) has occurred partly thanks to access to EU structural funds in Estonia since 2004. However, although the target of the overall absolute level of R&D expenditure was achieved, the GERD/GDP target has not been achieved (Reid, Walendowski, 2006); this is due to the rather high level of economic growth in Estonia during recent years. Increases in government expenditure have remained significantly below target (Reid, Walendowski, 2006)[17]. Although the ratio of business R&D to GDP is growing (in 2000 0.15, in 2005 0.44%), it is still almost 3 times lower than the EU15 (1.22% of GDP). Thus, a relatively lower proportion of R&D expenditure is made by

[16] For instance, Kobayashi (1999) found for Japan a strong positive relationship between the number of researchers in the private sector and the private sector R&D expenditure as a proportion to Gross National Product.

[17] The reasons might be that the EU structural funds replaced Estonian government funding but they were not added to the former; national technology programmes in the key sectors have not been launched; the financing has been based of the results of the annual negotiations instead of following the targets set in R&D strategy (Knowledge Based Estonia 2007-2013, 2006).

businesses (though in recent years business expenditure has grown faster than government expenditure).

Compared to R&D funding, funding for higher education relative to GDP in Estonia is much closer to the EU average. According to Eurostat, total public expenditure on tertiary level higher education was 1.05% in Estonia in 2003, the EU-25 average was 1.15%. Again, neighbouring countries Sweden and Finland are far ahead (in Finland 2.05%, in Sweden 2.16% of GDP).

In all countries of the world, PhDs constitute a rather small proportion of the total workforce. According to the census in 2000, there were at the age group of 25-64 years 1,906 persons with a PhD or equivalent degree, or 2.7 doctorates per thousand; that is a relatively low number if compared to countries like the USA (8.4), Canada (6.5) or Germany (15.4) (Auriol, 2007). The number of those in the economically active population was 2264 and those employed, 2237. The unemployment rate for PhDs was remarkably low compared to other educational levels. While the general level for unemployment was 13.9%, among those with a higher education, 5.1%, among those with a masters degree it was 1.9% and among the doctors a mere 1.2% in 2000[18]. This indicates the good performance of PhDs on the labour market. It has also been observed elsewhere that unemployment among PhDs is much lower compared to national averages; however, the Estonian numbers are also low in comparison with international figures[19]. Similarly PhDs are also characterized by a relatively low rate of inactivity (in 2000 20%; in OECD countries in the range of 7–23 %, Auriol, 2007). Another observation is that unemployment among PhDs is relatively unrelated to unemployment in the general population, and is less dependent on business cycles and macro-economic fluctuations (Shettle, 1997). Although we can’t construct a time series for PhD unemployment in Estonia, the same should also hold for Estonia given that unemployment among the general population was as high as 13.9% in 2000 following the economic downturn in 1999 caused by the economic crises in Russia. In 2000, PhDs constituted about 0.4% of the total workforce in

[18] According to the Estonian Labour Force Survey, the unemployment rate of PhDs was somewhat higher, 3.6 % in 2002. However in labour force survey the sample size of PhDs is too small to make any conclusions, thus the only reliable data about labour market situation of PhD holders are coming from census of population in 2000.

[19] Concerning the 7 OECD countries included in Auriol (2007), the PhD unemployment ranged from 2.3 % in Australia to 3.7 % in Canada. For US, different numbers have been reported, e.g. 2.9 for year 2003 by Auriol (2007) and 2.1 for the same year by National Science Foundation (2003). Regarding other countries, in Finland the PhD unemployment was 1.5 % in 2000 (PhDs in Finland 2003), in Canada 3.7 % (2001, McKenzie 2007), in UK 3.2 % (2004, graduates of 2003; UK GRAD Programme (2006)), in France 8.5 % (3 years after graduation; Martinelli 1999).

Estonia; concerning other countries, the percentage was 1% in USA, 2.8% in Switzerland and 2% in Germany (Auriol, 2007). PhDs were employed mostly in education (45%), research and development (20%) and public services (17%, see also Figure 1). In the non R&D business sector there were 17% of PhDs employed. Also these facts plus some anecdotal evidence from other former post-soviet countries tell us that due to low wages many promising PhD holders have left the academic sector and moved to the private sector. Given also the relatively low share of business R&D, the high-proportion of PhDs working in the business sector is thus due to reasons other than their engagement in business R&D.

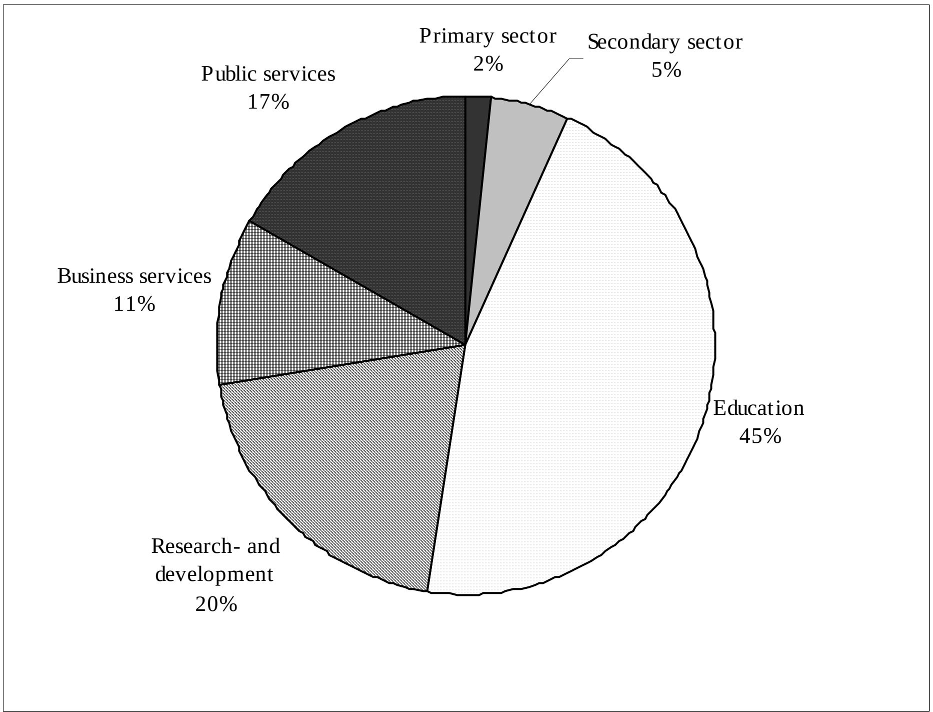

Figure 1 The employment of PhDs by sectors in Estonia, 2000

Source: Census of Population 2000.

Another important indicator of the performance of doctors on the labour market concerns their wages. For Estonia, analysis has been conducted based on income taxes paid on wage income after graduation (Kraut, 2005). The figures showed that the higher the level of higher education obtained, the higher also the sum paid as income tax (and hence wages). Relative to applied higher education, in the 2nd year after graduation those with a bachelor degree earned 38% more, those with a masters degree 86% more and those with a PhD degree 128% more[20].

[20] The numbers have been calculated by authors based on data from Kraut (2005). The numbers reported are averages from the period 2000–2003.

Concerning the age structure for doctors, the population is relatively old in Estonia compared to other countries. According to the 2000 census, the share of the population below 45 was 16% and over 55, 62%. Among 6 OECD countries, the USA had the oldest PhD population with 39% above the age of 55 (Auriol, 2007).

Table 1 R&D staff by level of education and sector

Sector	Level of education		1998	2000	2005
Higher education	Total		4475	4442	4591
		Incl. PhD	35%	34%	41%
		Master	13%	16%	25%
		Higher education	36%	36%	29%
		Non higher education	15%	13%	5%
State sector	Total		1280	1118	991
		Incl. PhD	24%	25%	21%
		Master	7%	11%	16%
		Higher education	41%	36%	48%
		Non higher education	28%	27%	15%
Non-profit private sector	Total		21	61	124
		Incl. PhD	48%	26%	24%
		Master	10%	15%	27%
		Higher education	33%	38%	42%
		Non higher education	10%	21%	6%
Business sector	Total		786	910	2249
		Incl. PhD	11%	7%	7%
		Master	0%	0%	0%
		Higher education	60%	62%	82%
		Non higher education	29%	31%	10%

Source: Statistical Office of Estonia

Note. Figures based on head-counts, not on full-time equivalent employees.

The Estonian Statistical Office gathers data about employees involved in R&D in various sectors (business sector, non-profit private sector, state sector, higher education sector). In 2004, the total volume of R&D personnel made up 1.32% of the total employment in Estonia; the average for EU-15 was 1.59% and for EU-24 1.49%; the proportion has increased recently in Estonia from 1.08 % in 1998. The proportion of those working in the higher education sector has decreased from 68% in 2002 to 58% in 2005; at the same time the share employed in the business sector has increased from 17% to 28%. There is a remarkable variation in the proportion of PhDs in total R&D personnel – while in the higher education sector 41% had a PhD, then in the state sector only 7% (Table 1). That indicates that on the basis of the same total R&D expenditure at the aggregate level, the higher share in business R&D implies a lower need for PhDs. Concerning other European countries, the share of total R&D personnel employed in higher education was much lower, in 2004 it was 43%. Thus, further growth in the volume of research personnel in Estonia should come from the private sector rather than higher education.

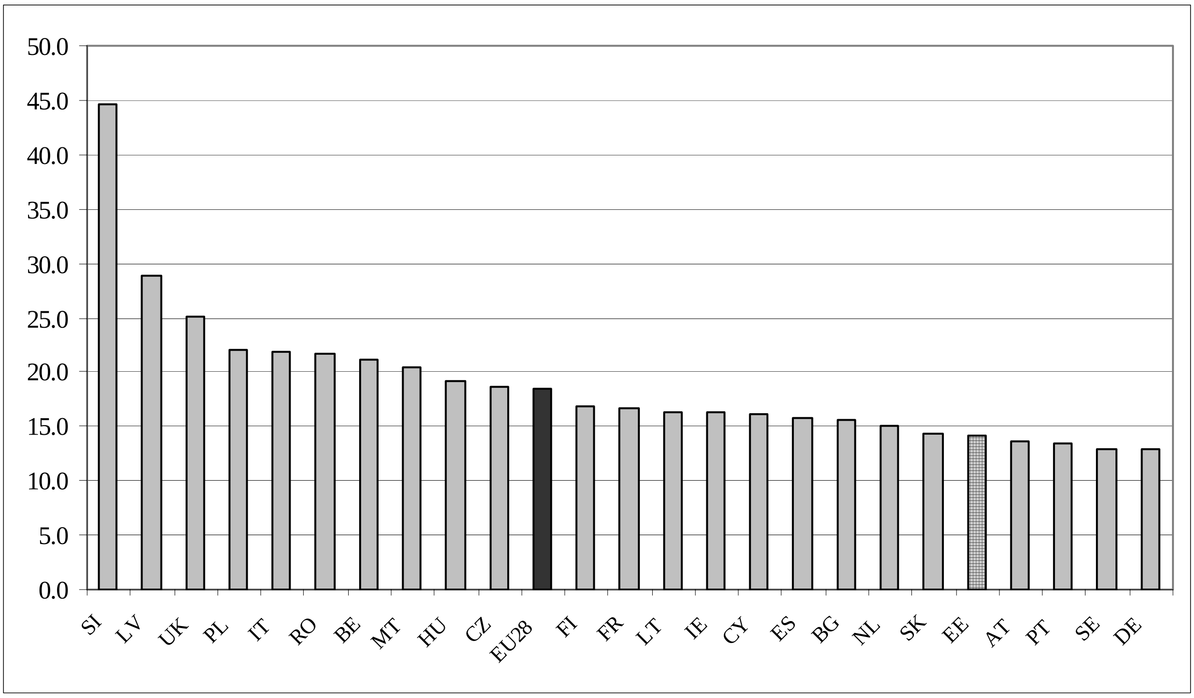

Figure 2 Student-to-teacher ratios in European Countries in 2003

Source: Eurostat.
Note. The measures are a ratio of students to academic staff at ISCED levels 5–6. The average for the EU is calculated without Luxembourg, Greece and Denmark, for which the data on academic staff was missing.

One particular indicator of the employment of PhDs in the higher education sector is the student-to-teacher ratio. Figure 2 presents these ratios for different European countries. As we can see, the value for Estonia (14.1) is quite close to the average for European Union countries (18.5). Thus, we cannot say that the number of teachers is low relative to students at the aggregate level, though across different disciplines the situation might differ considerably. The measure had the lowest value in Sweden and Germany (12.9) and the highest value in Slovenia (44.6). In the future, the number of students is expected to drop sharply due to demographic changes; although the ageing of population is visible in all developed countries, the changes are especially sharp in the Baltic States (Schlitte, Stiller 2007). A sharp drop in the number of students is foreseen because the sharp drop in birth rates at the beginning of the 90's will very soon be reflected in the size of the 16–18-year age group – forecasted to decrease from 64 thousand in 2003 to 44 thousand in 2010 and 33 thousand in 2015 (PRAXIS 2003). Still it will take a few more years before the impact will be visible on the number of university students. It is our conclusion that many academic staff need to move from teaching to research activities in order to preserve their employment in the academic sector.

There was a growth trend in the number of PhD defences in the 90s, when the number of PhD defences grew from 29 in 1995 to 135 in 1999. Thereafter, there was no clear trend – the number of defences increased to 226 in 2003, but thereafter dropped back to 143 by 2006. The priority in the Estonian education policy is to significantly increase the number of PhD defences. One particular policy instrument supporting this is the establishment of doctoral schools in 2004 with co-financing from EU structural funds[21]. The concern of the Ministry of Education and Research has been the low efficiency of PhD studies (in terms of the ratio of graduates to the number accepted into programs); as one solution, a scheme was launched in 2002 to direct PhD students to study in foreign universities for the entire length of their studies. The number of new students entering PhD programs has increased from 250 in 1995 to 370 in 2000 and 444 in 2006. Of these, 50% (2004) were financed by the Ministry of Education and Research; the other places were funded by the universities themselves (Statistical Office of Estonia; Ministry of Education and Research). The latter point indicates in our opinion that universities perceived the shortage of PhDs and they are trying to solve the problem by increasing the number of PhD candidates accepted. We will discuss later whether that is an appropriate strategy.

Concerning the structure of the Estonian higher education and R&D system, there are currently 11 universities and 20 institutions of applied higher education. To a large extent, PhDs are employed mostly in universities rather than in institutions of applied higher education. The graduate programmes exist in 10 institutions[22]. Many of the formerly independent research institutes (those under the Academy of Sciences) have now been integrated into the universities; although there also still exist some independent research

[21] One positive example in this respect was the introduction of doctoral schools in Finland; the first schools were created in 1995 and in 2003 there were already 114 graduate schools with 1,426 student places (PhDs in Finland…2003).

[22] These include 6 public universities (University of Tartu, University of Tallinn, Tallinn Technical University, Estonian University of Life Sciences, Estonian Academy of Music and Theatre, Estonian Academy of Arts), and 4 private universities (Estonian Business School, International University of Audentes, University Nord, Institute of Theology – Estonian Evangelical Lutheran Church). However, among private higher education institutions the PhD curricula lack official accreditation. According to our calculations, there were 209 curricula in doctoral studies, of which 119 had accreditation in the spring 2007. The relatively high number of curricula indicates the divisibility of the educational system.

institutes (those not associated with the universities). There are altogether 111 R&D institutions currently registered in Estonia in the Register of Research and Development Institutions, including 8 corporate bodies (6 public universities, Estonian Academy of Sciences[23] and one research institute). Most research performing institutions are institutes of other establishments or universities (34). Forty research institutions are registered under private law (including spin-off firms, foundations, etc), 18 of the research performing institutions belong to ministries (7 to MER, 1 to MEAC, 5 to Ministry of Agriculture, 3 to Ministry of Social Affairs, and 2 to Ministry of Culture). There is one research institution belonging to a local municipality (Tallinn Botanical Garden). Thus, due to the small size of the country, in each distinct field there are only a relatively small number of alternative institutions for PhDs where an academic can find work corresponding to their profession. Thus, within Estonia the opportunities for academic mobility are quite limited.

4. Method and data

Our analysis is based on the opinions of academic institutions about their current and future need for doctorates. Therefore, our study mostly involved analysis of the demand. Actual needs can also be estimated using other methods, such as quantitative models (as we showed in the literature review section). The method we used has both advantages and shortcomings. First of all we obtained direct information from employers actually hiring people with PhD degrees. They provided inside information about developments within the sector, future trends, potential student numbers, etc. Secondly, the majority of PhD holders are working in the academic sector, so we to a large extent covered the labour market for PhD holders.

The negative side of such a survey is the very subjective nature of the answers. The quality of the answers depends on the person who responded; if the respondent in particular institutions would have been different, also the answers might have been somewhat different. One question is how realistic are the prognoses and how sustainable are the institutions. The latter point mostly concerns small private institutions that entered the market recently. For example, the Estonian demographic situation is worsening, and the number of students will decline in the future (see last section). At the same time, many private schools did not see the declining

[23] Estonian Academy of Sciences does not undertake research itself. It has also practically no role in research funding.

number of students as a problem; also, they did not plan any increase in research activities at the same time. But they all saw an increase in the demand for PhD holders.

The information was gathered from the institutions using a form where questions were mostly with given answer choices (a few open-ended questions were included as well). There were 115 structural units interviewed, including 20 R&D institutions and 95 higher education institutions (see also Table 2). The total research and teaching stuff in these institutions was 3523, including 1465 academic doctors. It is difficult to estimate the representativeness of the sample in terms of the number of doctors in Estonia, as data on the latter is not available for every year. According to the census, 1460 doctors worked in education and research and development in 2000; according to our survey the number 5 years ago was 1454 (in 2001), or close to 100% of the number in census. The Statistical Office of Estonia collects data annually on employees involved in R&D. According to data from the Statistical Office of Estonia, our survey covered about 77% of all doctorates working in higher education institutions or R&D establishments[24].

Table 2 Descriptive statistics about the institutions surveyed and their sub-units

Indicator	**Humanities**	**Social sciences**	**Medical sciences**	**Real- and technical sciences**	**Total**
The number of questionnaires					
Number of units surveyed	27	39	5	43	115
Incl. R&D institutions	3	5	1	10	20
Incl. higher education institutions	24	34	4	33	95
Covered employees					
Total research and teaching stuff	757	992	377	1397	3523
Total number of doctors	222	269	209	765	1465
The proportion of doctors	29%	27%	55%	55%	42%
Total number of doctors in Estonia, 2005*	219	312	144	1225	1900
The proportion of doctors in institutions surveyed among the total number of doctors	101%	86%	145%	62%	77%
The average number of employees in the institution	18	13	25	18	15
The average number of doctors	5	4	14	10	6
The average proportion of doctors	39%	36%	37%	53%	43%
The standard deviation of the proportion of doctors	27%	20%	26%	24%	24%

Source: author's calculations according to the survey among Estonian higher education institutions and research and development institutions.
Note. Here the category of doctors includes all individuals with a PhD or equivalent degree.
* According to the data of the Statistical Office of Estonia (www.stat.ee), scientists and engineers with a doctoral degree in the higher education sector and private non-profit sector in 2005.

[24] According to the data of the Statistical Office of Estonia, the total number of scientists and engineers in the higher education sector in Estonia in 2005 was 1870.

The proportion varies greatly across fields and is lower among the real- and technical sciences. The proportion being higher than 100% in medical sciences as well as in the humanities is possible because, firstly, our data is on the basis of head counts, while the statistical office data considers full-time equivalent employees and in the latter source only the work-time devoted to research and development activities is taken into account; thus, for example, instructors need to divide their working time between research and teaching. Secondly, medical science institutions, for example, also employ researchers from fields other than medicine, such as biology, physics, etc. Thus, it is only a rather rough estimation of how representative our sample is. Still, we may infer that we have succeeded to cover most of the population.

In the category of doctorates, we included all those who had a doctoral degree or any other academic degree that has been assigned an equivalent status. In our case, the latter category included mostly those with a candidate degree (in Estonian: *teaduste kandidaat*, in Russian: *kandidat nauk*) that was given in the Soviet Union and is nowadays officially recognized as equal to a PhD.

The institutions surveyed break up as follows. Six of them are public universities: University of Tartu, Tallinn University, Estonian University of Life Sciences (*Maaülikool*), Tallinn Technical University, Estonian Academy of Music and Theatre and Estonian Academy of Arts. There were 81 units from universities, 14 from institutions of applied higher education and 20 from research institutions. Among the 115 questionnaires that were returned, 105 were completed either by public or state institutions (or their divisions), and 10 by private institutions (or their subdivisions). What have been left aside are the administrative departments of higher education and research institutions[25], funding agencies (like the Estonian Science Foundation), scientific libraries[26] and the Estonian Academy of Sciences. In the Estonian higher education system, the University of Tartu has a rather large role: it attracts about 48% of total research funding (2005), 60% of PhD graduates (2005) and more than 50% of the articles in ISI Web of Science[27].

[25] In some of these, the PhDs might be needed as well, for instance, in the departments dealing with issues of research and development.

[26] Nowadays also scientific libraries are becoming more important as employers of PhDs in US and other countries.

[27] The data is based on the annual reports of the University of Tartu and data from Estonian Statistical Office. In general, the Estonian system of research institutions is a rather modern one. Differently from the Soviet system, most research is undertaken in universities, and the academy of sciences has no research institutes of its own (with the exception of one institute).

The survey of the academic sector was undertaken in the spring of 2006. The data gathering procedure was as follows. At first the survey was sent to the respondents by e-mail and was followed by a face-to-face interview, if necessary. The individuals interviewed were sometimes the heads of the institutions, for instance, in smaller institutions; in larger institutions, such as universities, the leaders of subdivisions (departments or faculties) were interviewed (Table 3). The respondents were not employees of the personnel department, but individuals managing the institution or the department, so we can assume they had some idea about future developments or the future prospects of the institution. Although we directly interviewed only one person in each of the institutions, in many cases the questions were discussed with several individuals within the institutions and thus the answers reflected the collective opinion of the staff. In our study, our analysis was made across four scientific fields. These are the social sciences, humanities, real and technical sciences, and medical sciences. Such a distribution is in compliance with the classifiers of the scientific disciplines (Frascati Manual 2002, 2002). A similar division is also used by the University of Tartu, the largest university in Estonia.

Table 3 Overview of respondents by occupational position

Respondent	**Number**	**Percent**
Dean	12	10.4
Director	41	35.7
Head of department or institute	24	20.9
Rector or pro-rector	12	10.4
Other	26	22.6
Total	115	100

Source: author’s calculations according to the survey among Estonian higher education institutions and research and development institutions.

Next we will say a few words about the quality of our survey. One possible factor affecting the results might be self-selection: the institutions that have the greatest shortage of PhDs, might also be more willing to respond to the survey than those that do not need (or do not want) to hire additional doctorates (Basil and Basil, 2006). Some other problems were revealed from the feedback by the institutions refusing to fill in the questionnaire. For instance, one research institution claimed it is not possible to answer questions on vacancies, mobility, and so on, because the staff are not employed permanently, but for specific projects. Some institutions of applied higher education claimed they have no need for doctors because of the lack of master level curricula. Most of the respondents were, however, quite cooperative.

The total demand for doctorates has been decomposed as follows (see also Table 4). Firstly, we distinguished the replacement demand and growth demand. The replacement demand is connected to the replacement of the doctorates currently employed; that is, how many PhD defences we would need in order to keep the number of doctors employed at its current level. The second component is the growth demand, indicating the necessary growth in the total number of doctors based on the number of students, the volume of research and development activities and the desired proportion of doctors among all instructors and scientific workers. While the growth demand and total demand could be either positive or negative, the replacement demand is defined to be non-negative. Thus, in case leavers are not replaced with new faculty, there is a positive replacement demand that is offset by a negative growth demand, resulting in zero total demand (Shapiro 2001). Both, in the case of the replacement and the growth demand we distinguished current demand and future demand. The first shows the demand at the current moment, the second, at some point of time in the future by proceeding from some possible developments in the research and teaching activities.

Estimating the need for doctorates is a complicated research task because it involves forecasting the future. The latter involves a subjective component and the actual outcome (future developments) need not coincide with current opinions. There is inevitably considerable uncertainty in estimating the future. One factor that is fairly impossible to predict is future educational and economic policy decisions and their impact on the development of particular fields. While such decisions cannot be foreseen, we are able to analyze the future demand for doctors from the current situation.

The current replacement demand according to our approach involves people at or close to retirement age. Some individuals that have already reached the retirement age will, of course, continue to fulfil their functions for some time; however, sooner or later it will be necessary to find a replacement for them. The replacement demand in the future is connected to future retirements and the mobility of employees to other sectors (public sector, private sector) or to positions abroad. For instance, the employees currently close to retirement age will reach retirement age in the near future.

Table 4 The components of the total demand for doctors over 5 years

	Present demand	**Future demand**	**Total**
Replacement demand	Employees at retirement age	Retirements, movements to other sectors and abroad over 5 years	Total replacement demand
Growth demand	The readiness to hire new employees now: vacancies	The readiness to hire over the 5 next years minus the readiness to hire now	Total growth demand (how many employees we are ready to hire over the next 5 years)
Total	Total present demand	Total future demand	The number of new PhD's needed over the next 5 years

Source: authors' compilation

In the case of a growth in demand we distinguished replacement demand similarly between the readiness to hire new doctorates at the time of inquiry and the recruitment planned in the next 5 years. Growth in demand can be approached in different ways. One option is to ask the institutions, how many new doctors they would be ready to recruit if they had sufficient financial resources. The other option is to look at the unfilled positions or vacancies (e.g. Basil and Basil (2006) used job advertisement data). Unfortunately, experience has shown that without any financial guarantee, vacant positions will not be maintained. To some extent the logic of vacant positions works in the case of professorships, because there simply are no individuals with the necessary qualifications available. The nature of the vacant positions is, therefore, another *caveat* we need to keep in mind.

Next we will present some background information about the institutions and individuals surveyed. As shown in Table 5, on average 44% of all positions are filled by PhDs[28]. The lower the position, the lower the proportion of positions filled by doctorates; this stems from the logic of the positions at higher education and research institutions. As expected, the proportion of doctors is high, both among full professors (82%) as well as docents (77%); as a rule, the requirement of having a doctoral degree is also prescribed for professors and docents in the relevant job descriptions. The humanities are an exception, because in the case of some fields in the humanities (creative specialities) there is also no formal requirement in the law that professors are required to hold a doctorate, instead, it has been specified that the professorship should be filled by a creative person that has achieved international

[28] Concerning other countries, in Finland PhDs were estimated to account 25% of university staff (PhDs in Finland… 2003), in US accounting departments 55% (Campbell et al. (1990) and in US economics departments 73% (Cartter 1971).

recognition[29]. Thus, in the case of the humanities only a bit more than half (54%) of all professors hold a doctors degree, which is entirely due to the creative professions (fine arts).

Table 5 The relative importance of doctorates at various positions in educational institutions

Position	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
All higher education institutions					
Other teaching staff	8.6	5.2	22.2	12.3	10.0
Docent	44.4	89.1	100.0	92.8	78.9
Professor	55.7	97.1	100.0	94.9	83.8
Research staff	33.0	39.5	72.1	55.2	53.4
Total	29.0	35.4	55.2	56.1	44.3
Universities					
Other teaching staff	9.9	7.6	29.2	13.9	12.4
Docent	45.8	100.0	100.0	95.3	82.3
Professor	57.9	100.0	100.0	96.9	85.4
Research staff	33.7	39.5	72.1	55.4	53.6
Total	31.4	44.6	65.4	58.0	49.4
Institutions of applied higher education					
Other teaching staff	2.1	1.2	11.3	0.0	3.2
Docent	14.3	33.3		40.0	31.6
Professor	25.0	85.7		66.7	68.4
Research staff	0.0			0.0	0.0
Total	6.3	12.9	11.3	18.2	12.3

Source: own calculations based on the survey among Estonian higher education and research institutions.
Note. The group "other teaching staff" includes two categories, "Assistants" and "Lecturers". The group "Research staff" includes the categories "Research Fellow", "Senior Research Fellow" and "Lead Research Fellow".

The proportion of PhDs is expected to be lower in institutions of applied higher education compared to universities. For instance, in a study in polytechnics in Finland, just 5.2% of the full-time teaching staff had a PhD (PhDs in Finland…2003). In Estonia, the same figure is much higher for institutions of applied higher education at 12.3%. By field of study, the proportion of PhDs is higher in the real- and technical sciences, and lower among the humanities. The striking fact is that in institutions of applied higher education, the number of docents and professors that lack a PhD is not negligible (and that is not just in the humanities). Finally, the institutions of applied higher education have practically no research staff, which is not surprising.

[29] That requirement is specified in the requirements of the individual institutions as well as in the quality agreement between Estonian public universities (Eesti avalike ülikoolide kvaliteedilepe… 2003).

The staff in the category "Other teaching staff" as a rule do not have a doctorate degree. In the humanities, about one fifth of assistants have a doctors degree, but we can assume that these are mostly individuals at retirement age that are finishing their academic career lower positions than their candidate degrees obtained long ago would actually allow.[30] In medical sciences the proportion of "Other teaching staff" with a PhD is also not negligible. Appendix 1 also presents the results of a Tobit model for the proportion of PhDs. In institutions of applied higher education, the proportion of PhDs is significantly lower (by 30%) than in universities. In social science institutions, the ratio is 14% higher than in universities.

It has been noted that the employment prospects outside the public sector and universities are more limited in the humanities because this area is also divided into several smaller fields, and it is also more difficult to consider their needs in science policy planning (PhDs in Finland…2003).

5. Demand for PhDs in the academic sector in Estonia

Vacancies

Table 6 provides information about vacant positions. Generally, we can say that in about 60% of institutions or subdivisions there are unfilled positions, but the proportions are somewhat different across scientific fields. In terms of the total number of vacancies, the shortage of doctors is greatest in the social sciences and the situation is the best in medicine. In most cases the positions remain unfilled for 2–5 years. We can assume, that if a vacant position is unfilled for more than 5 years, then the position will be abolished at some point from the structure of the institution. The total number of vacant positions is 245, which constitutes 18% of the total number of doctors. That can be considered as a rather high proportion. The number of vacancies indicates the actual current need for doctors; there simply are not enough people with adequate qualifications. On the other hand, in many if not most cases, when indicating the number of vacancies, the respondents may have focused exclusively on unfilled professorships.

[30] According to the survey, in the humanities all the assistants with a doctoral degree worked in the Language Centre of the Faculty of Philosophy at Tartu University. Here we cannot rule out that the information reported in the survey is not entirely correct; for instance, some of these individuals might actually work as lecturers. The data from the personnel department of the University of Tartu on PhDs employed refer to that possibility. According to this source of data, these are indeed relatively aged employees.

Table 6 Vacancies and the reasons for their existence – a breakdown by fields (% of all units)

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
The units with vacancies (% of all units)					
Number of institutes	27	39	5	43	115
Unfilled for up to 1 year	33.3	35.9	60	25.6	32.2
Unfilled for 2-5 years	44.4	46.2	60	44.2	45.2
Unfilled for more than 5 years	3.7	12.8	0	9.3	8.7
Total	55.6	74.4	80	67.4	67
Number of vacancies					
Total number	48	93	24	123	288
Percentage of the number of doctors	21.6	34.6	11.5	16.1	19.7
The reasons of vacancies (% of all surveyed institutions)					
Own employee does not qualify.	37	46.2	40	41.9	41.7
No person with adequate qualification in Estonia	29.6	43.6	80	30.2	36.5
Too low pay	22.2	25.6	20	48.8	33
The peculiarity of research and working conditions do not allow to hire a foreigner	29.6	38.5	60	39.5	37.4
Contests					
The proportion of positions filled with actual competition, %	19.6	14.8	18.1	10.1	14.1

Note. Among units that indicated the presence of vacancies, there were a number of cases where the number of vacancies was not indicated, but it was indicated that there exists at least one since there was a reason for the existence of vacancies. We considered such institutions to have vacancies.

The reasons for the vacancies vary. Overall, the most common reasons were that the “our employees do not qualify” and “there is no one in Estonia with the appropriate qualification” – both were mentioned in 40% of cases. When taking these two reasons together, then in 55% of cases the problem was that there simply is no one in Estonia with adequate qualifications. At the same time, other problems were also mentioned, such as the low level of compensation for the work (the latter reason was indicated more often among technical and real sciences). Another factor, indicated by 36% percent, was that the specificity of the research work and the working conditions make employing foreigners impossible. That variant was chosen less often in research institutions compared to higher education institutions. That finding is in every way logical, given that in must curricula the studies are undertaken in Estonian. Perhaps an even more important conclusion we can make from these responses is that for most of the universities and R&D institutions that we surveyed, the academic job market is limited to Estonia. They did not mention budget restrictions as the main barrier to hiring new people (except in the real- and technical sciences). If they had thought internationally then with sufficient funding they could have afforded to hire people from Europe. But very few considered this as an option.

We were interested to discover the proportion of positions requiring a doctoral degree that have been filled as a result of genuine competition; that is, where there was more than one candidate for the position. As we can see from the table, the proportion of such positions is only 14%. Thus, till now the dominant practice is that there is only one suitable candidate for the position. This could also be interpreted that if there is a candidate with suitable qualifications, then the position will be created for him or her.

In institutions of applied higher education, there seems to be relatively more vacancies compared to universities. These vacancies constitute 63% of the total number doctors employed compared to 16% in universities (see Table 7). The numbers are also somewhat higher for research institutes, though the difference from universities is not so striking. There are many more vacancies in public and state owned institutions, than privately owned institutions. Thus, all–in-all, the situation seems to be the best in large public universities. The story behind this is most likely that the institutions that educate the doctors, seem to employ the majority of the PhD graduates themselves, and in that way there are not sufficient doctors for the other institutions. Another issue is the attractiveness of the working and salary conditions. Also, the surveys among doctors indicated that 75% of respondents considered their future to be connected with work in the academic sector (Puura *et al*, 2004).

Table 7 Vacancies and the reasons for their existence – a breakdown by type of institution

	Field of activity			**Ownership form**	
	Universities	**Applied higher education establishments**	**Research institutes**	**Public or state**	**Private**
The units with vacancies (% of all units)					
Number of institutes	81	14	20	105	10
Unfilled for up to 1 year	30.9	21.4	45	31.4	40
Unfilled for 2-5 years	44.4	50	45	43.8	60
Unfilled for more than 5 years	9.9	7.1	5	9.5	0
Total	64.2	71.4	75	65.7	80
Number of vacancies					
Total number	194	30	64	259	29
Percentage of the number of doctors	16	62.5	30.9	18.5	46

The reasons of vacancies (% of all surveyed institutions)					
Own employee does not qualify.	46.9	28.6	30	41.9	40
No person with adequate qualification in Estonia	35.8	28.6	45	34.3	60
Pay too low	32.1	35.7	35	34.3	20
The peculiarity of research and working conditions do not allow hiring a foreigner	37	35.7	40	36.2	50
Contests					
The proportion of positions filled with actual competition, %	13.6	30.8	10.3	14.1	14.8

Replacement demand

Next we will investigate replacement demand; that is, the component of total demand that is needed to keep the current number of employees with a PhD stable. Firstly, we will analyze the age structure of the doctorates. As we can see from

Figure 3, among doctors there is a very high proportion of workers at retirement age or quite close to retirement age – in total 53.2%. In the 2000 census, the proportion was 61.3% for all PhDs and for employed PhDs, 41% (the first of the census figures is higher due to retired people). There are certain differences across the scientific fields. Especially in the real and technical sciences this proportion is higher, in medicine and humanities it is somewhat lower (Table 8, Appendix 1). The proportion of older employees is also statistically significantly higher in research institutions as well as among institutions of applied higher education. The high proportion of PhDs at retirement age probably reflects various factors: the lack of new PhD graduates replacing the elderly workforce, the ability of PhDs to continue working at a relatively old age and poor retirement pensions[31]. That shows that while there have been rather strict retirement requirements in Estonia, universities have found ways to keep faculty that are above retirement age. For instance, people hired in teaching positions are transferred to research positions etc.

[31] In 2005-2006, there were special pensions only for the full-professor (in the form of salaries to *professor emeritus*). Since 2007, also the retired associate professors (*Docent emeritus)* receive similar fees. Concerning the possibilities to continue working after reaching at the retirement age, the regulations differ across institutions. In University of Tartu, it has not been allowed to work as an ordinary instructor after reaching the retirement age; however, it is possible to continue working in other positions, for instance as a research fellow.

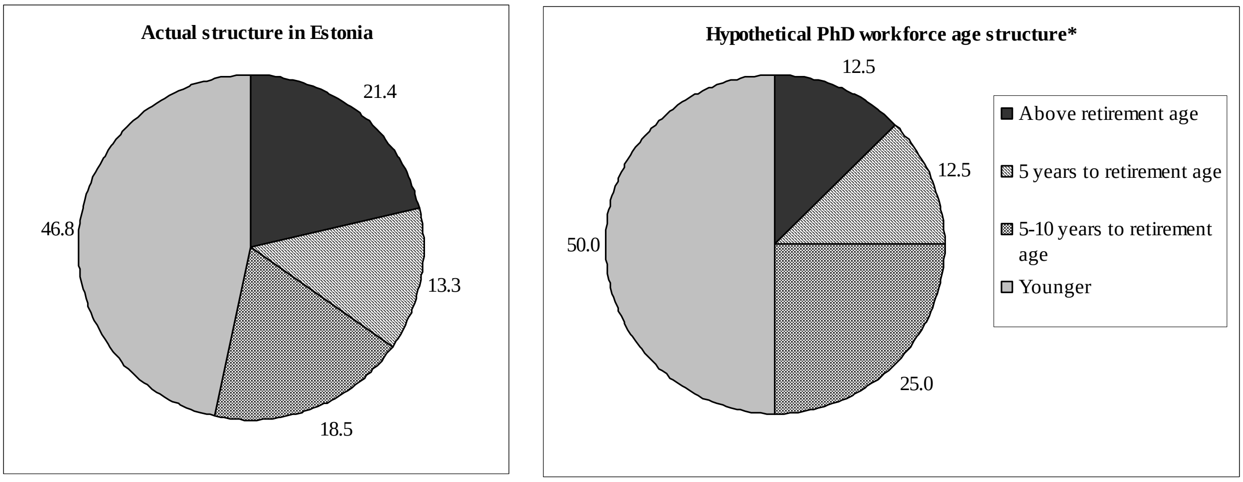

Figure 3 Replacement demand: the age structure of the doctoral workforce

Source: own calculations based on the survey among Estonian higher education and research institutions.
* In the calculations it is assumed that PhDs enter the labour market as PhDs at the age of 35, there is no net drop-out from academia (i.e. those leaving academia are balanced with those entering it), the retirement age is 65 and PhDs continue working till the age of 70 (similar assumptions have been made also in the literature, Shapiro, 2001).

It is important to take into account that PhD's enter the labour market relatively later than the other employees, during the period 1992–2002, the median age for PhD defence was 34 in Estonian universities (Puura *et al*, 2004)[32]; thus, it is normal that in the age structure of the doctoral workforce the relative importance of older age groups is relatively high. As a benchmark, we consider the case where PhDs enter the labour market as PhDs at the age of 35, there is no net drop-out from academia (i.e. those leaving academia are balanced with those entering it), the retirement age is 65 and PhDs continue working till the age of 70. In such a hypothetical case, the proportion would be depicted in the right panel of
Figure 3; that is, given these numbers, we would still consider the current age-structure in Estonia as abnormal. If we consider that there is a net departure of PhDs from academia[33] at some rate, then this would further increase the proportion of PhDs from the younger generations.

[32] According to the Auriol (2007), the average age at graduation ranged among OECD countries for men from 31.7 years in Italy to 38 years in Portugal, for women from 31.6 years in Italy to 38.1 years in USA.
[33] It might be non-feasible for PhDs to re-enter academia after working in other sectors due to evaporating skills or the motivation to work in academia having decreased due to better salary conditions elsewhere.

Table 8 The age structure of employees with PhD degree by academic fields

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
Research institutions					
Current number of employees with PhD	27.0	15.0	28.0	137.0	207.0
Above retirement age	29.6	13.3	14.3	32.1	28.0
5 years to retirement age	7.4	13.3	21.4	10.9	14.0
5-10 years to retirement age	11.1	26.7	7.1	12.4	13.0
Younger	51.9	46.7	57.1	44.5	44.9
Total: above the retirement age and up to 5 years to retirement age	37.0	26.6	35.7	43.0	42.0
Institutions of applied higher education					
Current number of employees with PhD	4.0	27.0	7.0	10.0	48.0
Above retirement age	50.0	40.7	42.9	50.0	43.8
5 years to retirement age	0.0	29.6	42.9	20.0	27.1
5-10 years to retirement age	0.0	7.4	0.0	20.0	8.3
Younger	50.0	22.2	14.3	10.0	20.8
Total: above the retirement age and up to 5 years to retirement age	50.0	70.3	85.8	70.0	70.9
Universities					
Current number of employees with PhD	190.9	229.0	174.0	684.0	1277.9
Above retirement age	8.4	14.8	0.6	22.2	15.9
5 years to retirement age	8.9	9.6	0.6	13.5	10.3
5-10 years to retirement age	17.8	19.2	1.1	18.3	16.0
Younger	64.9	56.3	97.7	46.1	57.7
Total: above the retirement age and up to 5 years to retirement age	17.3	24.4	1.2	35.7	26.2
Total sample					
Current number of employees with PhD	221.9	269.0	209.0	765.0	1464.9
Above retirement age	11.7	16.7	3.8	25.0	18.4
5 years to retirement age	8.6	11.5	4.8	13.6	11.5
5-10 years to retirement age	16.7	18.2	1.9	17.9	15.6
Younger	63.0	53.5	89.5	43.5	54.5
Total: above the retirement age and up to 5 years to retirement age	20.3	28.2	8.6	38.6	29.9

The previous evidence is in accordance with the fact that in the past the most important reason for leaving the job has been retirement (that has also been found to be true for other countries, e.g. Cartter, 1971): 48% of PhDs leaving in the last 5 years have done so due to retirement. Somewhat surprisingly, the other reasons for leaving, like going to work to abroad or transfer to the private sector, have a relatively low importance, respectively 10.4% and 6.4% of all leavers (see Figure 4). Leaving to go abroad has been more important among the humanities (4%) and social sciences (3.5%) than among medicine (2.6%) and real- and technical sciences (1.2%). The lower leaving rate in medicine might be a bit surprising, given the intensive emigration of doctors in Estonia to older EU member States (especially Finland and

Sweden)[34]. This variation is probably connected to the different age structure in different institutions (younger doctorates are more willing to go abroad); however in our data there was no correlation between the number of leavers and the proportion of doctorates younger than 10 years away from retirement age. Most of the respondents (59% in higher education institutions, 67% in research institutions) indicated that they expect the number of leavers to be the same in the future as it has been among the past; among others, those that expected the number of leavers to increase dominated somewhat over those that expected it to decrease (30% versus 11% in higher education institutions).

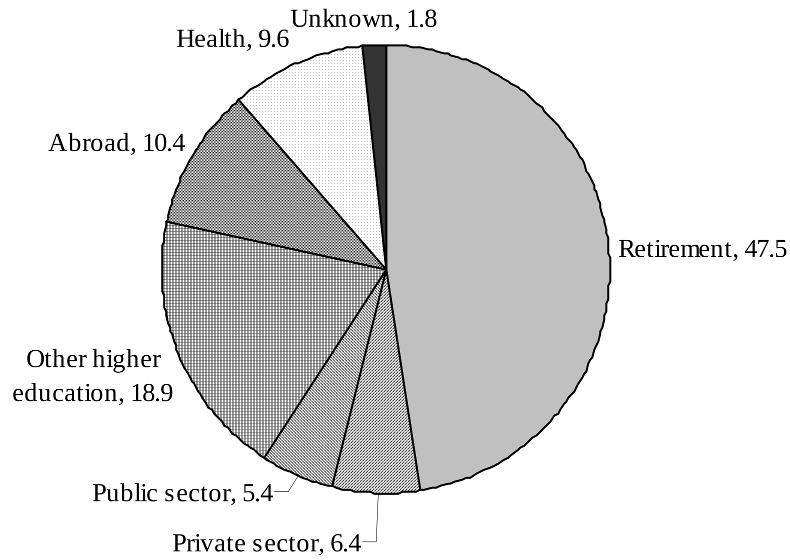

Figure 4 Replacement demand: reasons for leaving the job in the last 5 years, percentage of all leavers

Source: own calculations based on the survey among Estonian higher education and research institutions

From the reasons for the resignations we can also forecast the replacement demand for doctors over the 5 next years. Because we analyzed the demand for the entire academic sector, in constructing the forecast we did not take into account mobility between different higher education institutions – this represents a movement within the sector that cancels out at the aggregate level and does not have any impact on the final results (total demand for PhD’s in the academic sector). The expected number of leavers in the next five years has been

[34] The international mobility of doctorate holders has been studied by Auriol (2007). His data does not provide the leaving rates due to going abroad, but for instance the percentage of doctorate holders who are citizens of another country. That indicator varied from 0.2% in Argentina (2005) to 30% in Switzerland (2004). For Estonia we have no exact data, but it is probably rather low (far below 10%).

calculated as follows. The number of persons leaving due to retirement has been calculated as the sum of two categories, staff above retirement age currently employed and employees with up to 5 years till retirement age. For those leaving for other reasons, we proceeded from the actual number of leavers in the last 5 years; this is justified by the fact that most respondents expected the number of leavers to be roughly the same in the future. The results presented in Table 9 reveal that in the next 5 years, about 560 new doctors will be needed to replace the doctors currently employed in the academic sector – that makes about 40% of all doctors currently employed.

Table 9 Forecasts of the replacement demand for doctors in academic fields in the next 5 years

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
The current number of employees with a PhD	222	269	209	765	1465
The number of leavers for various reason as a % of the current number of PhDs					
Retirement	20.3	29.4	29.7	38.6	32.8
Private sector	1.0	1.7	0.0	1.9	1.4
Public sector	0.5	1.7	2.2	0.5	1.0
Abroad	4.2	2.9	2.6	1.3	2.2
Other	2.6	3.7	1.9	2.4	2.5
Total leave	28.6	39.2	36.3	44.7	40.0
Additional demand for doctorates	63	106	76	342	586

Source: own calculations based on the survey among Estonian higher education and research institutions.
Note. In this and the following tables, the value in the last column (Total) need not equal the sum of the demand in the sub/categories (here academic fields) due to rounding – the difference being just 1, however.

The replacement demand is much higher in institutions of applied higher education compared to universities (see Table 10); this is mostly related to the more unfavourable age structure in the latter. The differences between public or state, and private institutions are rather small. The replacement rate over 5 years is thus 40% and the annual average rate 8%. That estimate falls rather towards the upper end of the range of the values that earlier studies have either usually assumed or derived[35].

[35] Hansen et al. (1980) assumed 2% replacement rate for academic economists; McIver Consulting (2004) 7% for researchers in government sector and 10% for business sector; different earlier estimates for US faculty assumed 3-6% replacement rates (Cartter 1966), while Cartter (1966) calculated 1.9%.

Table 10 Forecasts of the replacement demand for doctors in the next 5 years on the basis of ownership form and field of activity

	Field of activity			Ownership form	
	Universities	**Applied higher education establishments**	**Research institutes**	**Public or state**	**Private**
The current number of employees with PhD	1210	48	207	1402	63
The number of leavers for various reason as a % the current number of PhDs					
Retirement	30.1	70.8	40.1	32.7	34.9
Private sector	1.5	2.8	0.5	1.4	0.0
Public sector	0.8	2.8	1.8	1.0	1.9
Abroad	2.2	0.0	2.8	2.2	1.9
Other	1.8	8.3	5.5	2.3	9.4
Total leave	36.4	84.7	50.7	39.7	48.1
Additional demand for doctorates	441	41	105	556	30

Source: own calculations based on the survey among Estonian higher education and research institutions

The desired proportion of doctors in total research and teaching staff

Another factor affecting the demand for doctors is the desired proportion of doctorates among all persons involved in teaching and research activities. The proportion of PhDs can be taken as a proxy for the quality of the research and teaching staff. We can see that on the average, 91% of institutions have indicated that their desired proportion of doctorates exceeds the actual proportion; so we can assume that in these institutions extra doctorates might be needed. However, the desired proportion may also be achieved by firing those staff without the doctoral degree. The desired proportion varies quite broadly (see Figure 5), however the majority has indicated that doctors should constitute 60–80% of all research and teaching staff. Concerning different academic fields, the desired proportion of doctorates is much higher in medical sciences and real- and technical sciences; the gap between the desired and actual proportions is quite large in all fields, though somewhat higher in medical sciences and the humanities. Based on this information, we have also calculated how many doctors would be needed to increase actual proportions to the desired level without firing any workforce without PhD degrees. As we can see from Table 11, the number is about 605 or about 45% of the current number of doctors, and that is definitely a rather high number. In such a situation, it is expected that employees without a PhD be expected to work towards a PhD; on the other hand, the question remains whether the heads of departments might still prefer to hire non-PhD workers in order to save on wage costs.

Table 11 Current demand for doctorates based on the desired proportion of doctorates in research and teaching staff

Additional need for doctors	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
The units where additional doctors are needed, percentage of respondents	92.6	89.7	100	88.4	90.4
The proportion of doctorates					
The desired percentage of doctorates, %	50.7	63.6	82.8	73.6	66.8
The actual percentage of doctorates, %	29.3	27.1	55.4	54.8	41.6
Units where the desired proportion is above the actual, %	66.7	76.9	100	65.1	70.4
Present number of doctorates	221.85	269	209	765	1464.85
The number of additional doctorates needed to achieve the desired percentage	162	362	103	263	890

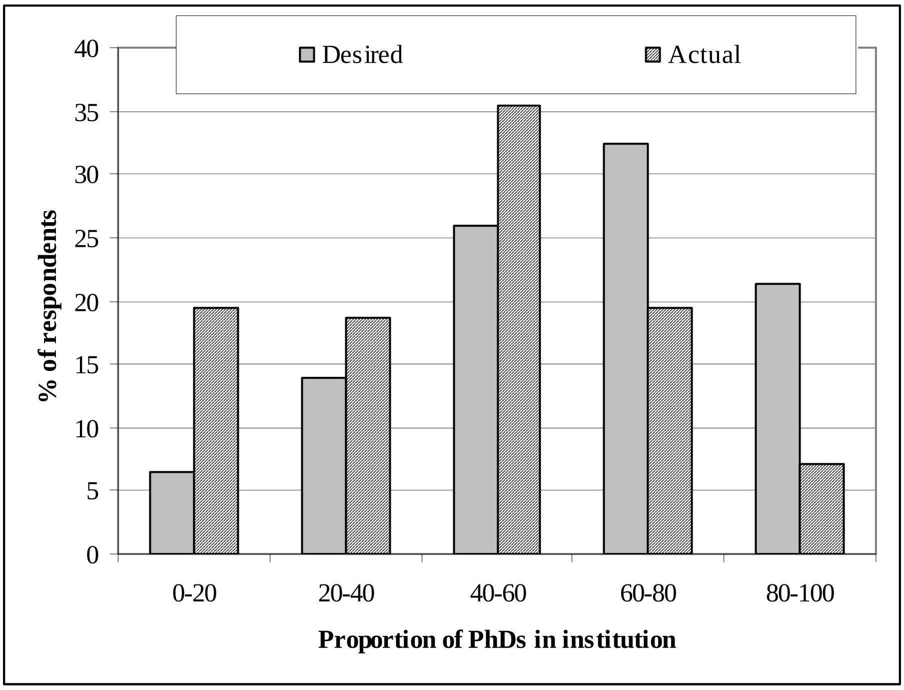

Figure 5 The desirable proportion of doctors among all teaching and research staff, percentage of respondents

Not surprisingly, the desired proportion of PhDs is much lower in institutions of applied higher education than in universities (respectively 72% and 25%). There is practically no difference between universities and research institutions, but in the latter the wedge between the desired and the actual proportion is much larger. The desired proportion is higher in public and state institutions (68%) than in private institutions (45%), probably because among the second group there are more institutions of applied higher education that do not have such ambitions for undertaking research. This is also confirmed via the regression analysis, where in the Tobit model for the desired proportion of PhDs, the only significant variable was the dummy for applied higher education (Appendix 1).

Growth demand and total demand for PhDs

As we have already mentioned, the growth in demand can be estimated in two ways, according to vacancies or, according to the stated readiness to hire new doctors in addition to those already employed at the institution. But, how many doctors do we need in order to increase the number of doctors currently employed (not considering the replacements for the currently employed workforce leaving for some reason). In our questionnaire we approached this issue in two ways. First, we asked respondents to report the number of additional people with PhD degree that are needed at the known level of funding, existing research projects and forecasted teaching load; that is, the need realisable within current resources. Secondly, we asked the respondents to report the need for PhDs if the financial constraints are discarded; such a figure could be determined by and originate from the development plan of the institution, for instance. This presents a kind of ideal situation. The results were in some sense surprising because the differences between the two were not perhaps as large as we would have expected. Within current actual resources, the institutions surveyed preferred to hire 588 additional doctors during the next 5 years, without funding constraints the number would be 828 (see Table 12, Table 13). Both of these numbers are rather high given the current number of doctors, the annual growth demand is respectively 8% and 11% over the next five years. Concerning previous estimates for other countries, this is a rather high figure, and the growth demand constitutes a remarkably high proportion of the total demand[36].

Table 12 Future growth demand for doctorates: planned hiring of PhDs in the future on the basis of scientific fields

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
Total hiring in the last 5 years					
As a percent	43	41.6	4.1	21.5	24.5
Number of people	83	101	11	161	356
Hiring within actual potential over next 5 years					
As a percent	54.1	60.6	10.5	37	40.1
Number of people	120	163	22	283	588

[36] In one study of the US faculty demand, new positions accounted only for 3–14% of the total demand (Shapiro 2001). In the study by Campbell *et al* (1990) on accounting faculty doctorates, the average replacement rate over 25 years was 2.8% and growth demand 2% of the number of faculty holding PhDs.

Hiring without financial constraints					
Immediate					
As a percent	34.3	36.4	10.5	28.6	28.3
Number of people	76	98	22	219	415
Over next 5 years					
As a percent	75.3	63.6	33.5	54.9	56.5
Number of people	167	171	70	420	828

Note. The hiring rates have been calculated across institutions as weighted averages, the weights being the institution's number of PhDs.

Table 13 Future growth demand for doctorates: planned hiring of PhDs in the future on the basis of ownership and field of activity

	Field of activity			Ownership form	
	Universities	**Applied higher education establishments**	**Research institutes**	**Public or state**	**Private**
Total hiring in last 5 years					
As a percent	23.9	69.4	20.2	23.3	54.7
Number of people	287	25	44	327	29
Hiring within actual potential over next 5 years					
As a percent	33.9	108.3	60.9	38.4	77.8
Number of people	410	52	126	539	49
Hiring without financial constraints					
Immediate					
As a percent	27	50	30.9	28.2	31.7
Number of people	327	24	64	395	20
Over the 5 years					
As a percent	53.5	118.8	59.9	55.6	77.8
Number of people	647	57	124	779	49

Note. The hiring rates have been calculated across institutions as weighted averages, the weights being the institution's number of PhDs.

Table 14 and Table 15 summarize the numbers on growth and replacement demand. We can generalize, that in the academic sector, total demand is in the range of 1100 to 1400 additional employees with a PhD degree, either for replacing the leavers or for increasing the total number of doctorates employed. That is a remarkably high number relative to the current number of PhDs (the total demand is almost 100% of the current number of PhDs). In the case of private institutions the ratio is 125% and in the case of institutions of applied higher education, 204%. We already referred earlier to the very optimistic expectations of some private institutions whose sustainability is questionable in the context of demographic changes and their limited research activities. Given that more than 90% of the demand for PhDs comes from universities and research institutes, these issues do not impact our final conclusions very much.

Table 14 Decomposition of the total demand for doctorates on the basis of scientific fields

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
Decomposition of demand: with constraints					
Replacement, immediate	26	47	36	191	300
Growth, immediate	48	93	24	123	288
Replacement, over 5 years	37	59	40	151	286
Growth, over 5 years	65	14	-2	152	231
Total demand	176	213	98	617	1105
Decomposition of demand: without constraints					
Replacement, immediate	26	47	36	191	300
Growth, immediate	68	68	22	215	373
Replacement, over 5 years	37	59	40	151	286
Growth, over 5 years	85	41	48	195	376
Total demand	216	215	146	752	1335

Source: own calculations based on the survey among Estonian higher education and research institutions

Table 15 Decomposition of the total demand for doctorates on the basis of ownership and field of activity

	Field of activity			Ownership form	
	Universities	**Applied higher education establishments**	**Research institutes**	**Public or state**	**Private**
Decomposition of demand: with constraints					
Replacement, immediate	221	21	58	283	17
Growth, immediate	194	30	64	259	29
Replacement, over 5 years	220	20	47	273	13
Growth, over 5 years	216	22	62	280	20
Total demand	851	93	231	1095	79
Decomposition of demand: without constraints					
Replacement, immediate	221	21	58	283	17
Growth, immediate	327	24	64	395	20
Replacement, over 5 years	220	20	47	273	13
Growth, over 5 years	320	33	60	384	29
Total demand	1088	98	229	1335	79

Figure 6 presents the relative proportions of the different components of the demand for doctorates across academic fields. As we can see, in the real and technical sciences the replacement demand constitutes a relatively large share of total demand (54%), although in this area the total number of the PhDs needs to be increased, too. In the humanities the share of replacement demand is relatively smaller (43%), because the age structure is somewhat more favourable, at the same time the growth demand is relatively larger. All in all, the share of growth demand is remarkable high, in a study on the faculty demand in the USA during 1987–2012 growth demand accounted for 3-14% of total demand (Shapiro 2001).

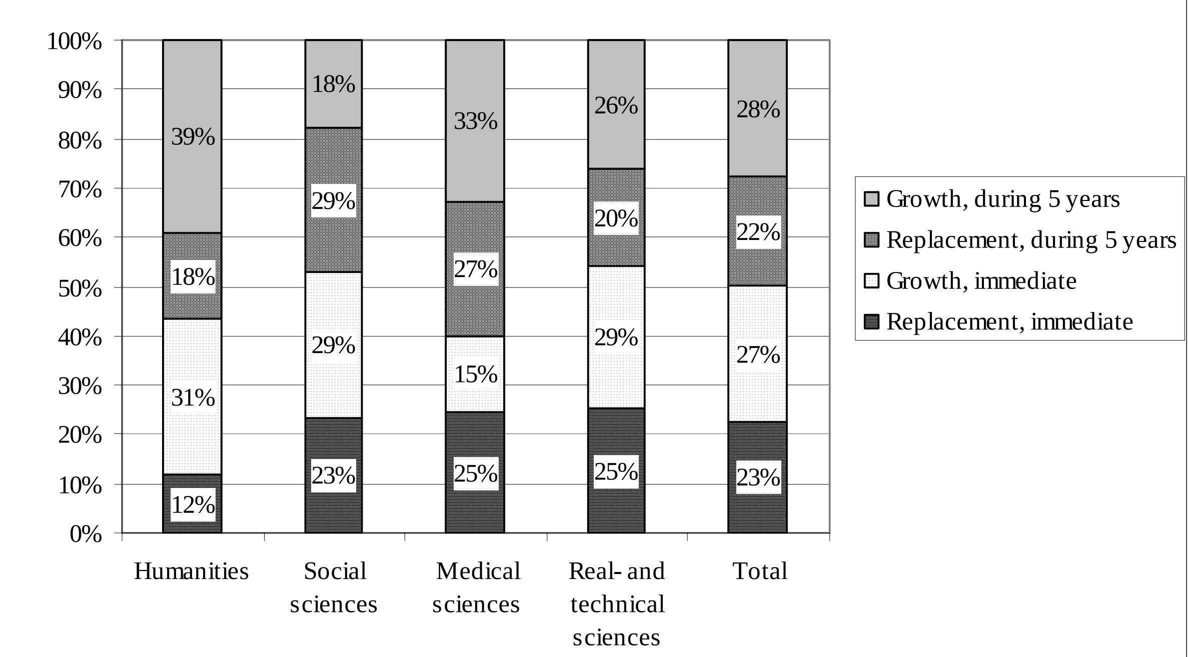

Figure 6. The components of the total demand on the basis of academic fields: relative proportions

Note. The growth demand has been calculated based on the need without financial constraints.

Comparing the demand, on the one hand, between private and state, and on the other, between private institutions reveals that private sector institutions have hired relatively many employees in the past as well as intend to hire quite many new employees in the future. Thus they have a relatively optimistic view of the future. Such optimism might be unjustified if the private institutions are not able to increase their engagement in research[37].

Does such a structure of estimated demand correspond to the current structure for the supply of PhDs in Estonia? As we can observe from Table 16, in the state financed study places the share of real- and technical sciences exceeds the share of graduates. That priority seems to be justified given the structure of the estimated PhD demand. In terms of replacement demand, the share of real- and technical sciences is even slightly higher. We might argue that in the case of the state being able to assign limited total funding to the financing of PhD education, attention should focus on the structure of the replacement demand. In general, the state financed study places still corresponds surprisingly well to the demand for PhDs.

---

[37] For instance in 2005 the private higher education institutions received less than 1 % of the total sum of the Estonian Science Foundation grants (own calculations based on the data of the Estonian Science Foundation, www.etf.ee).

Table 16 The breakdown of PhD supply and demand across academic fields, 2005

Academic field	PhD students	New PhD candidates	Graduates	State financed study places	Replacement demand	Total demand
Humanities	17%	18%	18%	13%	11%	16%
Social sciences	27%	25%	18%	20%	20%	20%
Medical sciences	6%	5%	13%	8%	13%	9%
Real- and technical sciences	50%	52%	51%	59%	57%	55%
Total	100%	100%	100%	100%	100%	100%

Source: Statistical Office of Estonia, Ministry of Education and Research,

The next issue is to what extent is the future demand for doctorates related to the expected future amount of and financing for research activities. The respondents' expectations for the volume of research work are presented in Figure 7 and Table 17. We can see that slightly more expect an increase in finances available than those who expect research funding to decrease. The vast majority still thinks that research funding will be approximately at the same level in the future. Research institutes are more optimistic compared to higher education institutions (the proportion of those expecting an increase in funding was 84% versus 19%). Concerning different scientific fields, the expectations are more optimistic among medical sciences; otherwise there are no significant differences between the disciplines. Growth in research funding is connected not only to PhD demand, but also the supply of PhDs; according to the survey of PhD students 1/3 mentioned difficulties because the supervisor did not have a targeted financed research budget[38], 71% indicated a shortage of funding for surveys, experiments, etc. (Puura *et al*, 2004).

The previous result is somewhat surprising given that the national policy documents have foreseen growth in research funding, namely that the total R&D budget should grow from the level of 0.88% of GDP to the level of 3% by 2013 (Teadmistepõhine Eesti …2006). That may indicate either a low belief among academic staff in the government's willingness to achieve set targets or that the respondents believe that funding will be directed to other fields than that of the respondents.

[38] Targeted funding is one of the most important public research funding instruments in Estonia. It is given for research teams for up to 6 years based on applications on specific scientific research topic.

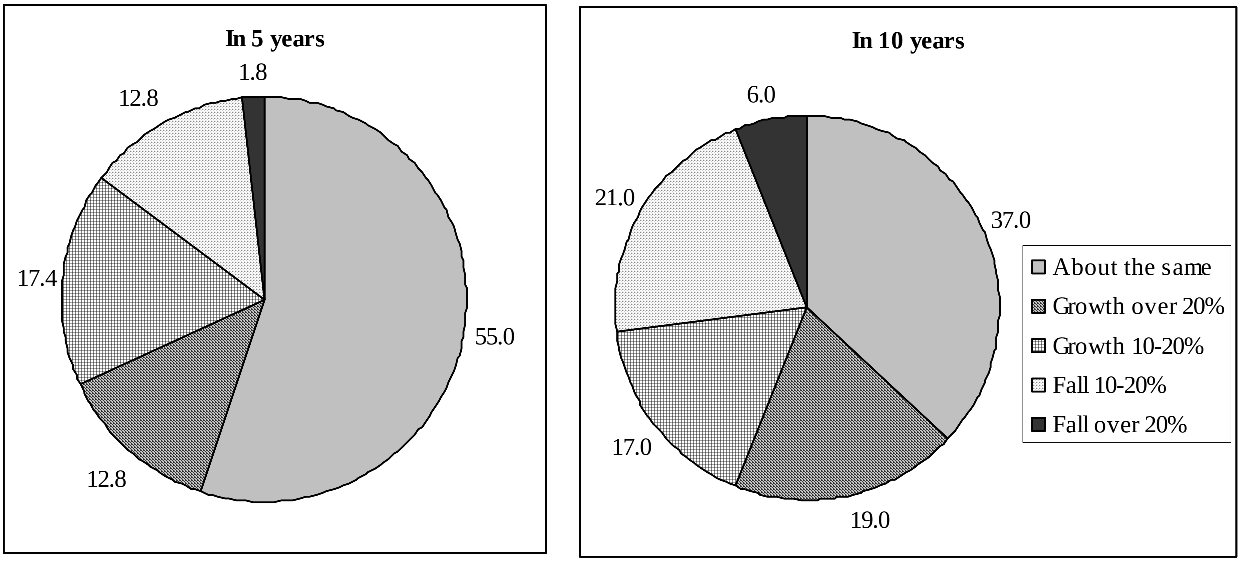

Figure 7 Expectations regarding changes in the volume of research

Table 17 Expectations regarding changes in the volume of research in 5 years

	About the same	Growth over 20%	Growth 10-20%	Fall 10-20%	Fall over 20%
Total	55.0	12.8	17.4	12.8	1.8
Ownership form					
Public or state	58.4	10.9	16.8	12.9	1.0
Private	12.5	37.5	25.0	12.5	12.5
Field of activity					
Teaching	63.3	7.8	11.1	15.6	2.2
Research	15.8	36.8	47.4	0.0	0.0
Scientific Field					
Humanities	58.3	16.7	12.5	12.5	0.0
Social sciences	54.1	13.5	16.2	13.5	2.7
Medicine	60.0	20.0	20.0	0.0	0.0
Real- and technical sciences	52.4	9.5	21.4	14.3	2.4

We can note that the estimated growth demand is quite closely associated to expectations of future research funding: the Spearman correlation coefficient is statistically significant at 0.24. The relationship is much stronger among universities than institutions of applied higher education, and surprisingly, research institutes (where the correlation coefficient is practically zero). While it is natural that institutions of applied higher education are not research oriented, in the case of research institutes, it may indicate either that their estimated future needs are unrealistic (the institutions did not consider the presence of funding when evaluating the demand) or that the necessary research funding for additional PhDs is already there.

In order to analyze the reliability of our findings, we hereby also present the correlations between various components of demand in Table 18: these are 1) vacancies, 2) estimated current replacement demand, 3) estimated future replacement demand, 4) estimated current growth demand, 5) estimated future growth demand, and 6) the number of additional PhDs needed to achieve the desired percentage of PhDs in total staff. As we can see, there is a positive correlation between the current and future replacement demand; that may appear mostly as a result of the age of PhDs – in institutions with a relatively high proportion of PhDs above retirement age there are also probably quite a lot of PhDs close to retirement age. Similarly, current and future growth demands are also correlated. Vacancies are especially strongly correlated with future growth demand: this might indicate that vacancies are not completely useless for estimating demand. Finally, the number of additional PhDs necessary to increase the proportion of PhDs to the desired level does not correlate with other variables, except future growth demand. This evidence should be taken to suggest that the questions in our survey worked at least at a satisfactory level.

Next we present the results of the regression analysis where various components of demand have been regressed on the basis of the different characteristics of the institutions. The results presented in Table 19 indicate that in none of the cases does the R-squared exceed 50%, indicating that a significant proportion of the demand is related to institution-specific factors not captured by the independent variables. The various components of demand are negatively related to the current number of PhDs.

Table 18 The correlations between the various components and proxies for the demand for PhDs

	Vacancies	Current replacement demand	Future replacement demand	Current growth demand	Future growth demand	Demand based on desired proportion of PhDs
Vacancies	1					
Current replacement demand	-0.0381	1***				
Future replacement demand	0.0291	0.3594***	1			
Current growth demand	0.2207**	0.1718	0.4015***	1		
Future growth demand	0.4514***	0.064	0.3699***	0.3652***	1	
Demand based on desired proportion of PhDs	0.1033	-0.1296	0.0522	0.1267	0.1789*	1

Note. * significant at 10%; ** significant at 5%; *** significant at 1%. All variables have been expressed relative to the total number of PhDs in the institution.

An expected growth in research funding will increase the future growth demand given the current financial constraints; however, an expected decline has no significant effect. The explanation for this might be that a decrease in funding is expected by institutions that have a relatively small proportion of funding coming from research anyway. A higher desired proportion of PhDs has a positive impact on PhD demand, but the variable is always insignificant. The vacancies-to-PhDs ratio has a significant negative effect on future growth demand – this might simply be because the higher number of vacancies means a higher current growth demand at the expense of a lower future growth demand. Concerning institutions of applied higher education, they have a much higher total replacement demand; but in the total demand the difference is no longer statistically significant. Not many significant differences can be observed between various scientific fields. In the real and technical sciences, the total replacement demand is significantly higher than in other disciplines (this is also reflected in Table 9); that seems to be the reason also for the higher total PhD demand.

Table 19 PhD demand component regressions

Independent variable	Future replacement demand	Future growth demand – with financial constraints	Future growth demand – without financial constraints	Total growth demand	Total replacement demand	Total demand for PhDs - without financial constraints
Log number of PhDs	-0.0452	-0.4261	-0.1985	-0.4261	-0.1304	-0.4599
	(-1.21)	(3.76)***	(2.65)***	(3.76)***	(1.66)*	(2.82)***
Research institution	0.0226	0.1293	-0.0502	0.1293	0.3149	0.1416
	(-0.2)	(-0.55)	(-0.24)	(-0.55)	(-1.2)	(-0.27)
Applied higher education institution	-0.1536	0.2778	-0.1618	0.2778	0.344	0.1178
	(1.86)*	(-0.74)	(-0.72)	(-0.74)	(2.65)***	(-0.4)
Private	-0.0693	-0.1937	0.0655	-0.1938	0.0451	-0.2498
	(-1.01)	(-1.02)	(-0.45)	(-1.02)	(-0.35)	(-1.14)
Medical sciences	-0.1179	0.0723	0.1763	0.0722	-0.0434	-0.0194
	(2.17)**	(-0.18)	(-0.7)	(-0.18)	(-0.29)	(-0.05)
Real- and technical sciences	-0.0478	-0.0544	-0.0612	-0.0545	0.2118	0.0792
	(-1.19)	(-0.51)	(-0.62)	(-0.51)	(2.30)**	(-0.42)
Research funding will grow	0.0105	0.4774	0.1643	0.4774	-0.0257	0.4379
	(-0.13)	(1.73)*	(-0.85)	(1.73)*	(-0.16)	(-1.11)
Research funding will decrease	0.0115	0.0556	-0.1011	0.0555	0.0599	-0.1151
	(-0.23)	(-0.41)	(-1.05)	(-0.41)	(-0.71)	(-0.73)
Vacancies-to-PhDs	-0.0002	-0.009	0.0002	0.001	-0.0007	0.0014
	(-0.32)	(5.22)***	(-0.18)	(-0.6)	(-0.75)	(-0.81)
Desired proportion of PhDs	0.1533	0.323	0.2159	0.323	0.1027	0.1647
	(-1.53)	(-1.61)	(-0.77)	(-1.61)	(-0.66)	(-0.65)
Constant	0.1716	1.1412	0.6399	1.1412	0.5108	1.9416
	(1.88)*	(3.44)***	(1.97)*	(3.44)***	(2.81)***	(4.28)***
Observations	87	100	95	100	100	91
R-squared	0.12	0.46	0.22	0.48	0.23	0.37

Note. Absolute values of robust t-statistics in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. All variables have been expressed relative to the total number of PhDs in the institution. The comparison groups are universities, public or state owned institutions, social sciences and humanities.

6. Conclusions and implications

The aim of the current paper was to estimate the need for new PhDs in the Estonian academic sector (universities, institutions of applied higher education, research institutes) in the next five years (2007–2012) by using the results of a survey undertaken among academic employers. As with earlier studies, we distinguished between the replacement demand (the demand resulting from the need to replace PhDs leaving due to retirements, deaths and net movements between the academic and non-academic sectors) and the growth demand (increase in the total number of PhDs employed). The results of our survey showed that the demand for new PhD's is rather high. The total number of new PhDs needed to replace leavers (mostly those retiring) and to increase the number of employed PhDs to the desired level constitutes almost 100% of the current number of PhDs employed in the Estonian academic sector. The rather high replacement demand has been caused by an unfavourable age structure within the PhD workforce that will cause high retirement rates in the coming years. In spite of that, the growth demand constitutes a higher proportion of the total demand than in many earlier studies. The shortage of PhDs in the academic labour market is evidenced also by the high proportion of vacancies (about one fifth of the total number of doctors) and the low proportion of positions filled via actual competition between applicants (in only 15% of all cases). The respondents also found that the proportion of PhDs in the total research and teaching staff should increase from the current 45% to about 60–70%.

Differences between scientific fields were not particularly noticeable. Privately owned institutions and institutions of applied higher education claimed to have a proportionally higher need for PhDs than public universities and research institutes. Their optimistic expectations for the future need not be realistic in the context of declining numbers of students and given their limited engagement in research activities. However, their share in total PhD demand in the academic sector is quite limited. In general, in the context of the expected decline in the number of students due to demographic changes, the level of research funding is expected to become a more important determinant of PhD employment. Although an increase in R&D funding is foreseen in national policy documents, the majority of respondents expected that funding would remain at its current level.

Thus, according to our estimations, the total demand for PhDs (the sum of the growth and replacement demand) in the academic sector will be in the range of 1100–1360 persons in the next 5 years. Such a need corresponds to the 220 to 270 PhD defences each year (about 15-18

% of the current number of PhDs employed). The total number of PhD defences in Estonian universities in 2005 was 131. In this study we only focus on the needs of the academic sector. Given earlier studies on PhD demand in other countries and the limited business R&D in Estonia, demand in the public sector (ministries, government agencies) and the private sector is very likely to constitute only a relatively low proportion of the total demand. Thus, the total annual demand for new PhDs in all three sectors might be relatively close to the figure of 300 that is the expert estimate suggested by the Ministry of Education and Research. Such a target is also written down in the national policy documents: according to Knowledge-Based Estonia 2007–2013 (2006), the number of PhD defences should reach 300 by the year 2013[39]. Given our results, the latter figure is rather an underestimation than an overestimation of the need. Thus, there seems to exist a significant unsatisfied demand.

The topic of this paper is not which policy measures should be used to close the gap. On the one hand, the domestic supply of new PhDs may increase if more individuals with master degrees choose to pursue a PhD due to reduced employment opportunities outside academia[40]. On the other hand, though the low public funding of higher education and research in Estonia is mostly considered an issue, in our survey the respondents sometimes seemed to forget that as the reason for the shortage of doctorates.[41] If the compensation for the scientific workforce was at an internationally competitive level, the international mobility of PhDs could solve the current shortage[42]. International mobility is therefore an important tool. More generally, a complex solution and policy mix is required to create a system that ensures the production and employment of PhDs in numbers that correspond to the foreseen growth of R&D expenditures and the establishment of a knowledge based society.

---

[39] Similar targets have also been set in other countries, for instance in Finland the development plan for education and university research set the target of 1,400 new PhDs during 2000–2004 (PhDs in Finland…2003). The R&D strategy document Knowledge-Based Estonia 2007–2013 (2006) specifies that the number of R&D employees should grow by 2013 to the level of 8 scientists and engineers among 1000 employees from the level of 5 in 2004. If sustaining the current proportion of PhDs among all scientists and engineers at 50% (in 2005 49%) and using the Ministry of Finance forecast for total employment (660 thousand in 2013), that assumes about 220 additional PhDs.

[40] In the case of Estonia, we have lots of anecdotal evidence that currently only mention that a slow-down in the Estonian economy (the GDP growth rate of 11.4% in 2006 is hardly sustainable) may increase the number of master students who choose to pursue a PhD through the lower opportunity cost of obtaining a PhD.

[41] Naturally, the attractiveness of the academic sector also involves other issues, such as how the positions for new PhDs are funded, are they permanent or temporary, etc. For instance, in Finland it was found that new PhDs have been recruited into universities mostly via external project funding allocated on a fixed term basis (PhDs in Finland…2003).

[42] The mobility of researchers in Estonia is studied in Archimedes (2007).

The demand for PhDs in the economy (especially in the public sector and business sector outside academia) is still minimised by a poor understanding of the meaning of a PhD degree and the role of PhDs in society. There is a widespread opinion in society that the only possible career for PhDs is within academia. Actually, a PhD is a sign of a rather highly qualified specialist who knows the theoretical foundations of his/her field and commands the necessary methodology in order to undertake empirical studies, critically analyze and evaluate new ideas and communicate with colleagues, the academic community and society. Employment either as an analyst in a ministry, as a scholar in academia or a top manager in a private company is a matter of the choice for each individual and the attitudes of society. In our future research we plan to continue with the study of PhD demand in other sectors of Estonia. The demand for PhDs in the public sector will be studied by means of a survey among ministries and government agencies, and the need for PhDs in the business sector will be estimated by means of modelling.

References

Archimedes (2007). Teadlaste mobiilsus Eestis ja seda mõjutavad tegurid. Sihtasutus Archimedes.

Auriol, L. (2007), “Labour market characteristics and international mobility of doctorate holders: results for seven countries”, *OECD STI Working Paper* No. 2007/2.

Basil, M. D., Basil, D. Z. (2006), “The marketing market: a study of PhD supply, demand, hiring institutions, and job candidates”, *Journal of Business Research*, Vol. 59, pp. 516-523.

Boddy, F. M. (1962), “The Demand for Economists”, *American Economic Review Proceedings*, 1962, Vol. 52, pp. 503-508.

Borthwick, S., Murphy, T. (1998), “Supply and Demand for Scientists and Engineers”, Department of Employment, Education, Training and Youth Affairs (Canberra, Australia) *Analytical Series* No. 98/4.

Bosworth, D. L. (1981), “The demand for qualified scientists and engineers”, *Applied Economics*, Vol. 13, Issue 4, pp. 411-429.

Braddock, D. J. (1992), “Scientific and technical employment, 1990-2005”, *Monthly Labor Review*, Vol. 115, No .1, pp. 28-41.

Brown, K. M. (1993), “Report of the Ad Hoc Working Group on the Supply of Science, Engineering and Mathematics (SEM) Professionals”, Washington, DC: National Science Foundation. [http://www.nsf.gov/sbe/srs/fccset/start.htm].

Campbell, T. L., Hasselback, J. R., Hermanson, R. H., Turner, D. H. (1990), “Retirement Demand and the Market for Accounting Doctorates”, *Issues in Accounting Education*, Vol. 5, Issue 2, pp. 209-221.

Cartter, A. M. (1966), “The Supply and Demand for College Teachers”, *Journal of Human Resources*, Vol. 1, Issue 1, pp. 22-38.

Cartter, A. M. (1971), “Whither the Market for Academic Economists”, *American Economic Review Proceedings*, Vol. 62, pp. 305-310.

Cox, B. G., Mitchell, S. B., Moonesinghe, R. (1998), “Current and Alternative Designs for the Survey of Doctorate Recipients. Task 1 Final Report”. Washington DC: Mathematica Policy Research. [http://srsstats.sbe.nsf.gov/docs/research/2-31.pdf].

Cruz-Castro, L., Sanz-Menéndez, L. (2005), “Incentives and flexibility. The employment of PhDs in firms: trajectories, mobility and innovation”, *Research Evaluation*, Vol. 14, No.1, pp. 57–69.

Eesti avalike ülikoolide kvaliteedilepe õppekavade, akadeemiliste ametikohtade ja akadeemiliste kraadide kohta (2003). [http://www.ut.ee/201824]

Forecasting Demand and Supply of Doctoral Scientists and Engineers: Report of a Workshop on Methodology (2000) Washington: National Research Council.

Frascati Manual 2002 (2002). Proposed Standard Practice for Surveys on Research and Experimental Development. Paris: OECD.

Freeman, L. A., Jarvenpaa, S. L., Wheeler, B. C. (2000), "The Supply and Demand of IS Doctorates: Past, Present and Future," *MIS Quarterly*, Vol. 24, Issue 3, pp. 355-380.

Godin, B. (2002), "Highly Qualified Personnel: Should We Really Believe in Shortages?", Project on the History and Sociology of S&T Statistics Working Paper No. 15 [http://www.inrs-ucs.uquebec.ca/inc/CV/godin/shortages.pdf].

Hansen, W. L., Newburger, H. B., Schroeder, F. J., Stapleton, D. C., YoungDay, D. J. (1980), "Forecasting the Market for New Ph.D. Economists", *American Economic Review*, Vol. 70, Issue 1, pp. 49-63.

Hermanson, R.H., Miles, C.E. (1976), "Fine-tuning the Predictive Model of the American Accounting Association 1971-72 and 1972-73 Committees on Future Professorial Supply and Demand", *The Accounting Review*, Vol. 51, No. 4, pp. 875-885.

Jones, E. (2002-03), "Beyond supply and demand: Assessing the Ph.D. job market", *Occupational Outlook Quarterly*, Vol. 46, No. 4, pp. 22-33.

Kobayashi, S. (1999), "Changes in the S&T Labour Market and Its Future: Are There too Many PhD Graduates", DSTI/STP/TIP(99) 2/FINAL, OECD, Paris.

Kraut, L. (2005), "Kõrghariduse omandanute ja õpingud katkestanute võrdlus töötasult laekunud tulumaksu põhjal". Tallinn: Poliitikauuringute Keskus PRAXIS. [http://www.hm.ee/index.php?popup=download&id=3951]

Lanciano-Morandat, C., Nohara, H. (2004), "The New Production of Young Scientists (PhDs): A Labour Market Analysis in International Perspective". *Danish Research Unit for Industrial Dynamics Working Paper* No. 03-04.

Leslie, L. R., Oaxaca, R. L. (1993), "Scientists and Engineering Supply and Demand" in *Higher Education: Handbook of Theory and Research*, Vol. IX. New York: Agathon Press, pp. 154-211.

Mace, J. D., Taylor, S. M. (1975), "The Demand for Engineers in British Industry: Some Implications for Manpower Forecasting", *British Journal of Industrial Relations*, Vol. X111, No. 2., pp. 175-193.

Martinelli, D. (1999), “Labour Market Performance of French PhDs: A Statistical Analysis” in *Mobilising Human Resources for Innovation*. Paris: OECD, pp. 100-123.

McIver Consulting (2004), “A Model to Predict the Supply and Demand for Researchers and Research Personnel in Line with Ireland’s Strategy for Contributing to the European Research Area 3% Initiative”. A Report Prepared for Forfas and the Expert Group on the Future Skills Needs. [http://www.skillsireland.ie/press/reports/pdf/egfsn040906_research_skills_report.pdf]

McKenzie, M. (2007), “Where are the Scientists and Engineers”, Statistics Canada, *Science, Innovation and Electronic Information Division Working Paper* No. 002.

National Science Foundation (2003). Characteristics of Doctoral Scientists and Engineers in the United States. Arlington: National Science Foundation, Division of Science Resources Statistics, NSF 06-320.

Pauli, A., Savunen, L. (2004), “Developing Finland’s Scientific Workforce”. [http://nextwave.sciencemag.org/cgi/content/full/2004/05/06/4]

PhDs in Finland: Employment, Placement and Demand (2003). Academy of Finland, Helsinki, Finland. [http://www.research.fi/k_tri_en.html]

PRAXIS (2003). Kutseõppeasutuste võrgu korraldamine lähtuvalt regionaalsest spetsialiseerumisest. Tallinn: Poliitikauuringute Keskus PRAXIS.

Puura, V., Lehtsaar, T., Kärner, A. (2004), ”Phare projekti ”Meetmete väljatöötamine doktoriõppe tugevdamiseks Eestis” aruanne”. Tartu: Tartu Ülikool.

Recotillet, I. (2003), “Availability and Characteristics of Surveys on the Destination of Doctorate Recipients in OECD Countries”, OECD, *STI Working Paper* No. 2003/9.

Reid, A., Walendowski, J. (2006), “Evaluation of the design and implementation of Estonian RTDI policy: implications for policy planning. Final report”, Technopolis Consulting Group Belgium SPRL, *Innovation Studies* 6.

Schlitte, F., Stiller, S. (2007), “Demographic Development and Challenges for Employment Change in the Baltic States”, in T. Paas and R. Eamets (Eds.), *Labour Market Flexibility, Flexicurity and Employment: Lessons of the Baltic States*. New York: Nova Science Publishers, pp. 21-40.

Shapiro, D. T. (2001), „Modelling Supply and Demand for Arts and Sciences Faculty“, *The Journal of Higher Education*, Vol. 72, No. 5, pp. 532-564.

Shawver, D. L. (1973), “The Supply and Demand for New Marketing Doctorates”, *Journal of Marketing*, Vol. 37, Issue 2, pp. 63-67.

Shettle, C. F. (1997), “Who is unemployed? Factors Affecting Unemployment among Individuals with Doctoral Degrees in Science and Engineering”, Arlington: National Science Foundation, Division of Science Resource Studies, Special Report, NSF 97-336.

Sumell, A. J., Stephan, P. E., Adams, P. E. (2005), “Capturing Knowledge: The Location Decision of New PhDs Working in Industry”. Youngstown State University, mimeo. [http://www.econ.upf.edu/crei/activities/wokshops/innovation/papers04-05/stephan.pdf].

Teadmistepõhine Eesti 2007-2013. Eesti teadus- ja arendustegevuse ning innovatsiooni strateegia. (2006) Tallinn: Teadus- ja Arendusnõukogu.

UK GRAD Programme (2006), “What do PhDs do? A regional analysis of first destinations for PhD graduates”. [http://www.grad.ac.uk/cms/ShowPage/Home_page/Resources/What_Do_PhDs_Do_Regionally_/p!eeXmdpp]

Appendix 1. Overview of selected studies on the estimation of demand for PhDs

Author(s)	Subject	Methodology	Sector	Factors influencing the demand	Main findings
Cartter (1971)	US, academic economists (teaching faculty)	Calculations based on changes in enrolments and new doctorates	Academic sector (teaching faculty)	Enrolment estimates, marginal student/staff ratios, demographic changes, college attendance rates. Replacement demand is due to deaths and retirements.	Forecasted disequilibrium in academic labour market in economics (supply exceeding demand), that will result in underemployment of PhD's in academic sector and more PhDs in government, industry, teaching posts in lower levels of education.
Bosworth (1981)	UK, qualified scientists and engineers in manufacturing industry	Formal econometric model	Manufacturing industry	Demand in 4 fields (production, R&D, implementation and testing of new technologies, marketing) depends on the size of respective activities and relative factor prices	Low elasticity of substitution of scientists and engineers on the one hand and other inputs on the other, the demand for scientists and engineers is most sensitive towards R&D costs compared to industrial output, investment and advertising.
PhDs in Finland… (2003)	Finland, all scientific fields and sectors (academia, private and public sector)	Interviews in private and public sector, interviews with PhD graduates, use of existing databases and analysis	Academic sector, public administration, private sector	Changing industrial structure, growing investment in business R&D, demographic developments, increasing competency requirements in different tasks	The demand for PhDs is expected to increase in private and public sectors. 8 % of interviewed companies considered it important to hire PhDs. In private sector, the demand is highest among larger firms.
Freeman et al. (2000)	North America, information systems doctorates in academic sector	Survey of universities on information systems doctorates demand and supply	Academic sector	Estimates of demand based on universities self-evaluations.	Imbalance between supply and demand (demand exceeding supply) that cannot be corrected in the short-term (structural imbalance)
Basil and Basil (2006)	US, marketing	Analysis of job advertisements and the registration of employers at academic placement service; survey of institutions and job candidates	Academic sector	No analysis of specific factors	The shortage of faculty is explained both by the disequilibrium between supply and demand (due to falling PhD supply) as well as the mismatch between the qualifications of candidates and the job requirements
McIver Consulting (2004)	Ireland; PhD and non-PhD researchers in private R&D by various manufacturing and	Industry level analysis based on employment projections of various industries that are used to derive projections	Various manufacturing and services industries (private sector)	Industry: employment by industries, share of research staff in industry employment, ratio of PhDs to non-PhDs; constant annual replacement rate at 10% is	For the R&D expenditure to achieve 2.5% of GDP, number of researchers should grow by 44%. A shortage of both PhD and non PhD graduates is expected that will limit R&D growth in Ireland.

Author(s)	Subject	Methodology	Sector	Factors influencing the demand	Main findings
	services industries; higher education and government research	for research staff. Higher education and government – projected number of researchers are derived from research spending projections		assumed. HE and government – projected changes in research funding (different scenarios), gross national product projections, cost per researcher; constant 7% annual replacement rate.	
Hansen et al. (1980)	US, Ph.D. economists	Econometric model consisting of equations on PhD demand, PhD supply, entrants to graduate programmes, new PhDs	Academic and government sectors	Academia: changes in wages, research funding, undergraduate and graduate enrolment. Government: changes in wages, federal and local government expenditures.	In the short run, wages will decline to achieve equilibrium on the market; .decline in the share of PhDs going to academia; in the long run the lower salaries cause less students to enter economics programmes.
Mace and Taylor (1975)	UK, engineers, industry	Case studies of firms via personnel interviews, questionnaires to engineers	Industry	Hiring costs of labour with different qualification, conditions of internal labour markets of some specific firms	Positions of engineers are filled by employees with different qualifications; qualified engineers are not necessarily working in positions in accordance with their profession.
Bortwick and Murphy (1998)	Australia, scientists and engineers (not only PhDs)	Non-formal discussion	Some discussion of public sector and industry	Economic growth, technological development, R&D costs, government priorities, vacancy levels, demographic factors	Majority of science and engineering graduates are not engaged in R&D There is some evidence of oversupply of people with scientific training along with shortages in some specific fields (mining engineers and for computer professionals; secondary school teachers in mathematics and science)

Source: The authors' compilations based on the sources indicated in the table.

Appendix 2. Tobit model regression results on the proportion of PhDs in total teaching and research staff, and age structure.

Dependent variable	Actual proportion of PhDs	Desired proportion of PhDs	Proportion of people at retirement age or less than 10 years to retirement
Research institution	-0.0343	-8.6827	0.2250
	(0.58)	(1.36)	(1.83)*
Applied higher education institution	-0.3010	-35.9140	0.4725
	(4.42)***	(4.91)***	(3.08)***
Private institution	-0.0471	-11.6259	-0.1108
	(0.61)	(1.33)	(0.69)
Medical sciences	-0.0023	18.0404	-0.1369
	(0.04)	(1.42)	(0.54)
Real and technical sciences	0.0822	2.6659	0.2272
	(0.73)	(0.43)	(2.03)**
Social sciences	0.1472	2.0837	0.2040
	(2.61)**	(0.32)	(1.77)*
Constant	0.4188	64.7417	0.3473
	(9.37)***	(12.75)***	(3.94)***
Observations	113	108	95
Log-likelihood	-5.07	-460.09	-63.25

Absolute value of t statistics in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%