Estimating the need for PhDs in the academic, public and private sectors of Estonia

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Abstract

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. The aim of the current paper is to estimate the need for new PhDs in the Estonian academic, public and private sectors for the 5-year period 2007-2012. The need in the academic and public sectors is estimated from the survey of employers (universities, research institutes, ministries etc.), the need in private sector is derived from the forecasted expenditure on R&D in the business sector. Our results show that expectedly the demand for PhDs is in public and private sectors significantly lower than in academic sector. The total demand over 3 sectors is rather high, annually more than 10% of the current number of PhDs, caused both by the high replacement demand brought on by retirements in the next years and the growth demand. 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.

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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 proportion of researchers in the in the labour force is often used as an indicator of knowledge base of the society.

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

[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).

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 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. The aim of the current paper is to estimate the need for new PhDs in the academic, public and private sectors of Estonia, a small country in Eastern Europe with a catching-up economy, over the 5-year period 2007-2012. While the biggest proportion of PhDs is employed in all countries in the academic sector and much less elsewhere (e.g. in Estonia there is employed in the private sector only about 10% of the doctoral workforce)[6],

[5] This figure includes those who spend at least 10% of their working time on research and development activities.

[6] In 2000 among all employed PhDs 85% were employed in the research and development sector including the R&D activities of the higher education sector. In 2006 83% of R&D employees with PhD were employed in the higher education sector. In public sector there were working 9% and in private sector only 8% of R&D employees with PhD degree (Eesti Statistika: Rahvaloendus 2000, T&A statistika 2000).

the latter proportion is increasing. The PhDs employed in the private sector are important for ensuring the innovativeness of the economy and for the transfer of knowledge from academic to the private sector. Especially the tacit knowledge can spread from academic to private sector if the PhD students after graduation start working in the private sector (Mangematin and Robin 2003).

Our estimations on the demand in the academic and public sectors will be based on a survey of employers, such as universities, institutions of applied higher education and research institutes, ministries, government agencies. The demand in the private sector is estimated with a structural model from the forecasted dynamics of R&D expenditures. 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 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. Especially interesting is the case of Estonia – the R&D system is on the hand very small with total R&D expenditure in 2006 just 150 million euros, but its growth rate has been recently one of the highest in the EU (45% increase from 2005 to 2006, only below that of Latvia), highly concentrated academic sector with the largest institution University of Tartu accounting for about 50% of the total research funding. 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].

[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 both academic, public and private sectors. We will attempt to find evidence that either confirms or disproves these numbers.

The rest of the paper is structured as follows. The following section reviews existing literature on the demand for PhDs; here we aim to cover the analysis of the need for PhDs in academic as well as public and private sector, but 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 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

[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.
[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

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 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

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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).

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 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

[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.

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]. Shortly, the modelling of business sector demand for PhDs has followed one of the three approaches:

- structural modelling: by comparing the demand and supply of PhDs the number of growth demand, replacement demand and supply are calculated;
- based on the questioning of employers bys asking their opinion about the doctorates' growth and replacement demand;
- benchmarking by using some other country as a desired target fir future developments;
- estimates based on the performance of PhDs in the labour market: the relatively high wages or their very low unemployment might refer to their lack in the economy. That approach needs also relatively detailed data, preferably micro-data, but both wages and

[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).

unemployment are good indicators about information on the relation between demand and supply in the labour market.

The first of the approaches is most demanding with respect to the necessary data and it assumes normally the availability of a good database on the PhDs or the arrangement of a special survey. As an example of such kind of approach, Marey et al. (2001) compared the supply and demand of science and technology graduates of EU14 countries. The demand was modelled separately for 3 sectors (private sector, government sector, higher education sector). The number of scientists and engineers employed (measured in working hours) or the growth demand was modelled with an error correction model, where the explanatory variable was the sectors' expenditures on research and development activities. Thus, the approach assumed that there is a long-term relationship between the working hours of scientists and engineers on the one hand and the R&D expenditures on the other hand. The replacement demand was estimated from the age structure of the workforce and the flows to the positions other than those of scientists and engineers. 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. 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, 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 advantage of this approach is that requirements towards necessary data are smaller and the possibility to learn from the experience of the other country. The limitation of this approach is that there are no two identical countries: the regularities observed at some point of time need not to hold later despite on how similar are the two compared 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 –

[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.

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 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

In this section, we review the position of PhD's in the Estonian labour market in international comparison. The exact numbers on their employment rates, unemployment rates as well as other indicators are available from the census of year 2000, while for later years the estimates from other databases like the labour force surveys are rather imprecise due to the small percentage of PhDs in the population and in the most survey samples. The indicators can be found also in Table 1. 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). In total population there were 2,833 persons with a PhD and equivalent degree, or 0.21% of the total population. In Finland the corresponding number was in year 2000 0.27% and in 2004 0.35% (Statistics Finland 2007, Eurostat 2007). The number of those in the economically active population was 2264 and those employed, 2237. The estimate on the growth of the share of PhDs in population from 0.2% to 0.6% according to Estonian LFS data is in our opinion unrealistic, we think that the reported 22% growth during 5 years in the number of PhDs working in the R&D sector of Estonia is more realistic.

Table 1 The socio-economic status of PhDs ands those with equivalent degree in Estonia and other countries

	Estonia, Census	Estonia, LFS		OECD	Finland	Canada
	2000	2001	2005			
Number of PhDs surveyed	2833	24	55			
The share of PhDs in population (%)	0,21	0,19	0,57			
PhD employment rate * (%)	78,96	52,5	82,3			
Employment rate* (%)	51,1	51,4	53,5			
PhD unemployment rate * (%)	1,19	2,9	0			
Unemployment rate * (%)	13,6	12,6	7,9			
PhDs working in R&D	1894	1945	2304			

* 15 years old and older.
Source: Census 2000, Estonian Labour Force Survey, Statistical Office of Estonia.

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[16]. 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[17]. 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). The possible explanations are their later retirement and less frequent flow into inactivity, caused by the high opportunity cost of non-working. 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

[16] 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.

[17] 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).

constituted about 0.4% of the total workforce in Estonia; concerning other countries, the percentage was 1% in USA, 2.8% in Switzerland and 2% in Germany (Auriol, 2007).

As expected, according to the Census PhDs were employed mostly in education (45%), research and development (20%) and public services (17%, that includes also medical services, see also Figure 1 and **Error! Reference source not found.**). Quite big differences can be noted between the different sources of data – according to the R&D statistics 81% of all R&D personnel was occupied in education sector. Thus supposedly many PhDs in the private sector are working in jobs where they not deal with R&D activities, hence we may argue whether they are over-qualified for their current job. At the same time even 85% of the PhDs are occupied in R&D activities and even when all R&D workers are employed in the private sector, the census data and R&D statistics are not comparable. For instance in 2000 according to census data there were 1019 PhDs employed in education while according to R&D statistics there were 1530 R&D employees with PhD. In 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.

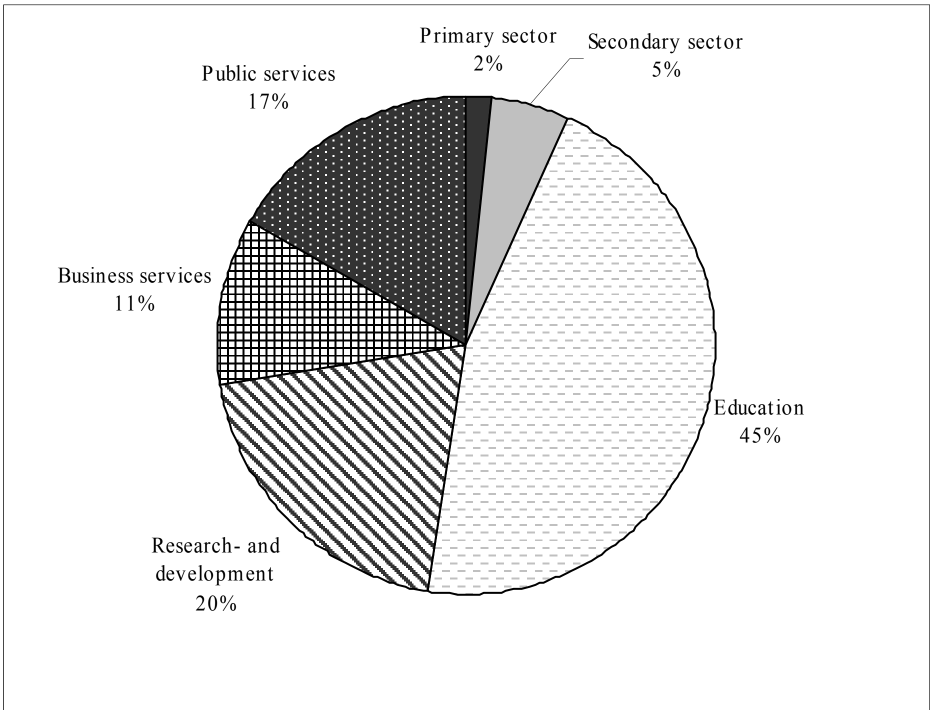


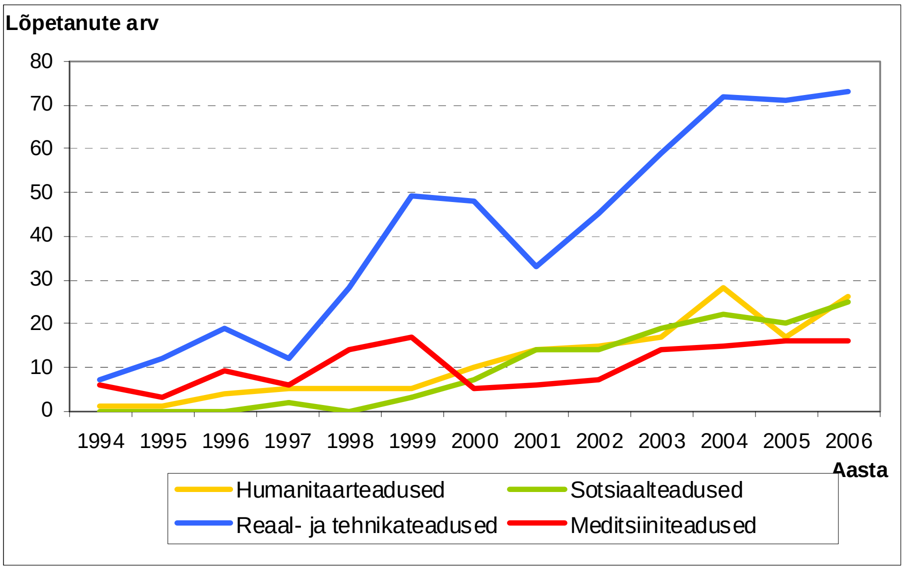
Figure 1 The employment of PhDs by sectors in Estonia, 2000
Source: Census of Population 2000.

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%; the estimates from Estonian LFS for later years give only rather imprecise numbers. Among 6 OECD countries, the USA had the oldest PhD population with 39% above the age of 55 (Auriol 2007). Thus, expectedly the replacement demand constitutes a rather high share of the total schooling demand, during the next 15 years the number of the PhDs leaving the labour market will be twice as high as the number entering from the next age group (respectively 1152 PhDs at the age group 50-64 and 651 at the age group 35-49). The situation is somewhat alleviated by the high economic activity of the PhDs that have exceeded the retirement age.

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[18]. In a later study by Rõõm (2007) about the wages of graduates of vocational and higher education institutions it was concluded that during the period 2000-2004 the wage differences of individuals with different educational background have decreased. There seems to be no benefits from acquiring the PhD after the master's degree, i.e. while 2 years of master studies increase the wages by 39%, then 6 additional years in master's and PhD programme increase wages only by 39%. When other control variables are considered (academic field, sector of employment), the wages of masters' are 22% lower than those of . Thus, it seems that the PhD degrees are obtained in fields where the wages are lower (humanities, arts) and they work in sectors with lower wages (education). There was no statistically significant difference between the wages in public and private sectors in case of individuals with higher education. The study by Cruz-Castro and Sanz-Menéndez (2005) showed that in Spain the motivation to work in private sector was connected to wages but rather to the desire to obtain professional experinec in the private sector or the lack of stable job in the public sector.

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

There has been a growth trend in the number of PhD defences during 1995-2005, the number of PhD defences grew from 14 in 1995 to 140 in 2006[19]. The number of defences is biggest among natural and technical sciences (see also Figure 2). A constant growth trend is visible in all fields, the rapid growth in medical sciences during the end of 90s has later continued at a lower speed. The annual average number of PhD defences was during 2002-2006 118. 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[20]. 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 ordered 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.



[19] The numbers reported in the graduates of the residentuur have been excluded from numbers of new PhDs hereby.

[20] 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).

Figure 2 The number of graduates of PhD programmes (ISCED6 level)
Source: Eesti Statistika 2007.

Concerning the international mobility of PhD workforce, Murakas et al. (2007) found from the survey carried through among the scientists, instructors and PhD students that Estonian scientific environment is characterized in international comparison by poorer remuneration, infrastructure and the qualification of scientists in the specific area of the respondent. From the positive side better possibilities for an academic career were indicated. About one third of the foreign scientist that had worked in Estonia had a strong plan to continue working in Estonia, about 20% of Estonian scientist that had worked or studied in abroad intended to stay and work permanently in abroad.

The total employment of PhDs is certainly connected to total expenditure on research and development[21]. 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)[22]. 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 businesses (though in recent years business expenditure has grown faster than government expenditure).

[21] 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.
[22] 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).

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).

Table 2 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 2). 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.

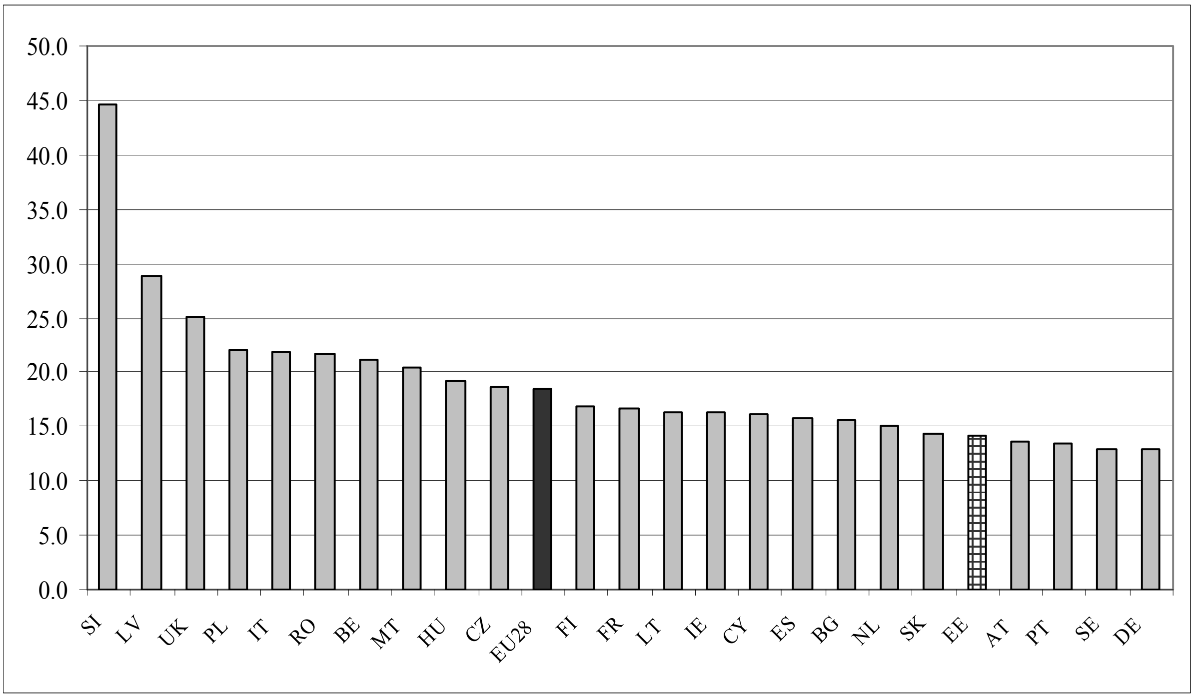


Figure 3 Student-to-teacher ratios in European Countries in 2003

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 3 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 (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.

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[23]. 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 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[24] 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

4.1. Academic sector

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.

[23] 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.

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

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 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 3). 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[25].

[25] 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.

Table 3 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.
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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, 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[26], funding agencies (like the Estonian Science Foundation), scientific libraries[27] 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[28].

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 4). 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 public University in Estonia.

[26] In some of these, the PhDs might be needed as well, for instance, in the departments dealing with issues of research and development.
[27] Nowadays also scientific libraries are becoming more important as employers of PhDs in US and other countries.
[28] 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).

Table 4 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.

The total demand for doctorates has been decomposed as follows (see also Table 5). 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 5 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 6, on average 44% of all positions are filled by PhDs[29]. 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 recognition[30]. 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 6 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

[29] 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).
[30] 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).

Position	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
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.

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.[31] In medical sciences the proportion of "Other teaching staff" with a PhD is also not negligible. When using a Tobit model to model the proportion of PhDs (results are not reported to save space), 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).

[31] 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.

4.2. Public sector

The demand in the public sector was estimated by using the survey of employers. In addition to estimating the demand for PhDs the purpose was also to map the need for analytical work in public sector, is the analysis performed in-house or outsourced extramurally, the added value from the PhDs in the public sector and the reasons for their do far low employment in the public sector. In the 1st step we tried to form an exhaustive list of the state institutions that might have any interest to employ doctorates: ministries, agencies, inspections, foundations, bodies governed by public law. In case of ministries, we tried to get information for their central administration and not to cover the whole area under the respective ministries's administration (the other agencies under the ministries were interviewed separately if necessary). In principle, the different institutions were divided into three groups. Firstly, the institutions that according to the available information engage in analytical work (indicated e.g. by the presence of an analysis department or the jobs) were surveyed with a longer of the questionnaire. Secondly, the institutions with limited engagement in analytical work were surveyed by using a shorter version of the questionnaire. Thirdly, the institutions where in our opinion no need for PhDs existed were left out of the analysis. The main survey was again preceded by a pilot survey after which the questionnaire was somewhat modified. The questionnaires were first sent by e-mail and later the institutions were also contacted by phone. The overall response was rate about 53% that can be considered a rather satisfactory result. The time of the survey was December 2006 till June 2007. Altogether 29 questionnaires were received back. The people questioned were once again not the representatives of the personnel departments, but from the administration or directorate of the institutions. We assumed the surveyed persons to have some vision about the institutions future developments and needs. Still, the results are dependent on the competence of the surveyed persons.

In the surveyed institutions there worked altogether 7541 employees, 81 or 1% of them had a PhD degree. The survey thus covered about 20% of the employees working in the sector „Public administration and national defence". At least 1 person with PhD degree worked in 19 institutions, the proportion of PhDs was highest in the Ministry of Education and Research (7%) and the State Agency of Medicines (6.8%). The PhDs worked more often in the positions of analysts, professionals, middle managers, counsellors, in these positions worked 80% of the PhDs. In % of institutions (4 out of 17) there existed positions where PhD was required (also preferably) in the job description. Among the PhDs, 14% had the degree in the field of Humanities, 22% in Social Sciences, 16% in Medicine, 33% in real and technical sciences, for the rest (17%) the degree is unknown.

4.3. Private sector

Differently from the academic and public sector, we considered to be the questioning of employers not to be an appropriate approach in order to find out the demand for PhDs. That is because among all doctors only 10% are employed in the business sector. In addition to that, many employers might not understand the contents of the PhD degree and thus are unable to give an adequate forecast for the demand of PhDs. Thus we used the structural approach to the modelling of PhD demand. We used the official R&D statistics and to lesser extent Estonian labour force survey data for the analysis[32]. Although the census data on the number of PhDs and their distribution is most reliable, that is available only for 2000 and thus cannot be used whereas for forecasting a dynamic data is needed. R&D statistics is collected on annual basis, however problem is the relatively short time series (8 years) that does not enable the compilation of a more sophisticated econometric model. The comparison of the census and R&D statistics reveals that in 2000 85% of doctors employed in Estonia worked in the R&D sector. Thus the R&D database covers a large proportion of the Estonian doctors and thus that data is mostly used in the analysis. The data from Estonian Labour Force Survey includes annually just 20-50 PhDs, thus any estimates other than their proportion in population are too imprecise. We present two forecasting scenarios: the continuation of the previous development trends and the intensive growth of R&D expenditures that involves closing the gap with the model country. Thus, the other scenario can be considered the combination of the structural method and the model country (benchmarking) approach.

The forecast for PhDs was based on structural modelling. It means that we estimated separately the growth demand and replacement demand for PhDs in the private sector. Hereby growth demand considers the additional need for PhDs that follows from the enlargement or contraction of different economic sectors. Replacement demand indicates the number of currently employed PhDs that need to be replaced in the future because of retirement; we did not consider other reasons why the PhD might left the private sector (like migration to abroad or movement to other economic sectors

[32] Edaspidi on doktorikraadiga isikute statistika osas kajastatud ISCED97 kuuenda taseme haridusega isikud. Eesti puhul koosnevad ISCED97 kuuenda taseme koolitusala lõpetanud vaid PhD kraadiga isikutest (1998-2005), Soomes ja ka teistes Euroopa Liidu riikides ei pruugi ISCED97 kuuenda taseme lõpetanud olla phd kraadiga. (Eurostat 2007)

We follow to large extent the approach of Marey et al. (2001). Firstly, at the modelling of the growth demand we make the rather strong assumptions that PhDs are needed in the private sector only in positions related to R&D activities and secondly that the need for PhDs is determined by the amount of investments into R&D. We distinguished 3 broad economic sectors; these were the primary, secondary and tertiary sectors. We could not undertake the analysis at a lower level of aggregation due to the rather low number of R&D employees in many of the industries. Primary sector was excluded from the analysis as there were during 1998-2005 no R&D employees with PhD and the R&D investments of this sector were at a very low level as well.[33]. For R&D PhDs employed in non-profit sector no data on the breakdown by economic sectors is available. Because of that the need for PhDs in this sector was modelled separately. Thus, we modelled the need in three sectors: secondary sector in pursuit of profits, tertiary sector in pursuit of profits and nonprofit private sector.

The rather short available time-series on R&D expenditures, 1998-2005 (in non-profit private sector 1996-2006) sets constraints on the list of different econometric approaches that can be used. Thus the use of error correction model is not reasonable on the Estonian data and an ordinary regression model is used instead. As a first step, the dependence of R&D investments on the linear time trend is modelled:

(1) $I_t^{T\&A} = \alpha_1 + \beta_1 T_t + \varepsilon_t$, $t=1,\ldots, 8,$

where $I_t^{T\&A}$ denotes that R&D investments in the economic sector (in millions of kroons, constant prices of year 1998[34]), T_t is time trend and ε_t represents the error term. In the 2nd step the need for PhDs in the sector is modelled as a function of the R&D investments using the following simple regression equation:

(2) $L_t^{Doktorid} = \alpha_2 + \beta_2 I_t^{T\&A} + u_t$, t=1, …, 8,

where $L_t^{Doktorid}$ denotes the number of R&D employees with PhD employed in the sector and u_t is the error term. Based on this relationship between linear time trend and R&D

[33] Aastal 2005 olid primaarsektori T&A investeeringud kokku 0,9miljonit krooni (1998.a. hindades). Sekundaarsektoris olid T&A kulutused ühe doktorist T&A töötaja kohta 7,3 miljonit krooni ja tertsiaarsektoris 2,4miljonit krooni (kulutused 1998.a. hindades). Teiste sektorite praktikat järgides peavad primaarsektori kulutused T&A-le kasvama kordades, enne kui nad T&A doktoreid vajada võiksid.

[34] In order to convert the R&D expenditures into constant prices we used in case of the secondary sector the producer price index and in case of tertiary and nonprofit sectors consumer price index.

expenditures (equation (1)) the sector's R&D expenditures for the period of 2006-2011 were forecasted (see also lisa 3). The forecasted R&D expenditures were added as an input to the equation on the demand for PhDs (2) and thus the forecast on the demand for PhDs for the period 2006-2011 has been obtained.

As a third step, the forecasted total number of R&D employees was allocated between 4 fields of education: Humanities and Arts (No. 2 in ISCED97), Social Sciences (No. 1 and 3 in ISCED97), medical sciences (No. 7 in ISCED97) and real- and technical sciences (No. 4, 5, 6 and 8 in ISCED97 "4, 5, 6, 8"). Because the data on the allocation of business sector R%D employees across activities and fields of education was not available, the data from the Estonian Labour Force Survey was used to find proxies. As the survey included only 55 PhDs in 2005, we used instead the data on the distribution of professionals across sectors and fields of education (see tabel 4). That proxy should be appropriate as a specific distribution of professionals across sectors assumes a similar distribution of employed PhDs. In case of non-profit private sector, the distribution of scientists and engineers with degree across fields of education was available in the national statistics. The distribution of professionals across fields of education sectors is used for dividing the total growth demand for PhDs across fields of education. We also assume that the distribution across the fields of education stays constant during the period of forecast.

Table 7. **The distribution of professionals across fields of education and sectors, 2005.**

	Humanitaar-teadused	Sotsiaal-teadused	Meditsiini-teadused	Reaal- ja tehnikateadused
Kasumitaotluslik sekundaarsektor (ETU)	0%	21%	6%	73%
Kasumitaotluslik tertsiaarsektor (ETU)	14%	42%	5%	39%
Kasumitaotluseta easektor (T&A statistika)*	6%	25%	0%	69%

*Doktorikraadiga teadlased ja insenerid kasumitaotluseta erasektoris.
Source: Estonian LFS, R&D statistics, own calculations.

Concerning replacement demand, because the national statistics does not produce data on the age structure of the business sector R&D employees, we have assumed that the age structure of the PhDs working in the academic and business sector is the same, and thus we have used the replacement rate due to retirement that was estimated for the academic sector. Thus, in case of replacement we consider only replacements due to retirement. That assumption can be justified on the basis that according to the available data the flows of PhDs between the private and academic sectors are rather modest in Estonia; similar results have been found also for other countries[35]. Also, the differing wage levels should not motivate the movement of people with higher education from public to private sector (Rõõm 2007).

5. Demand for PhDs in the Estonia

5.1.Academic sector

We start the presentation of the results from the academic sector; expectedly most of the PhD demand comes from this sector, thus the situation in this sector affects also that in the other sectors – e.g. in case of large shortage in academic sector it might be difficult to satisfy also the needs of the public and private sectors. We start the analysis from the vacant positions (see Table 8) that may show the presence of unsatisfied demand. 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 (245) constitutes a rather high proportion (18%) of the total number of doctors. 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.

Table 8 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

[35] Cruz-Castro and Sanz- Sanz-Menéndez (2005) found from the survey of PhDs in Spain that once academic or private sector has been chosen for employment, the person will stay there for a longer period of time. Mangematin (2000) found for French engineering PhDs that the decision to work either in private or academic sector influenced the behaviour of an PhD candidate already before the graduation, i.e. those planning to work in the academia publish more and those who are planning tow work in the private sector cooperate with the private sector already at the beginning of the PhD studies.

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
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
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

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 existence of vacancies vary. Overall, the most common reasons were that "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. Another factor, indicated by 36% percent, was that the specificity of the research work and the working conditions make employing foreigners impossible. That finding reflects the facts that in must curricula the studies are undertaken in the Estonian language. One conclusion that 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 (vacancies constitute 63% of the total number doctors employed compared to 16% in universities). 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 (large public-universities), 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).

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 (VIIDE). 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, technically the desired proportion may also be achieved by firing those staff without the doctoral degree. The desired proportion varies quite broadly, 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 (respectively 83 and 74%); 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; the number is about 605 or about 45% of the current number of doctors, 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.

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. It must be considered that while in the Soviet Union most of the research was done in the institutes of the academy of sciences and universities were more specialized on teaching, after the fall of communism the institutes of the academy of sciences have been integrated with universities and more generally higher education sector has been transformed into research performer. 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).

We next move on to the analysis of replacement demand; that is, the component of total demand that is needed to keep the current number of employees with a PhD stable. Starting with the age structure of the doctorates (retirement is usually considered the most important source of replacement demand), we can see from Figure 4, among doctors there is a very high proportion of workers at retirement age or quite close to retirement age – in total 45.5%. 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 9). 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[36]. 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.

[36] 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.

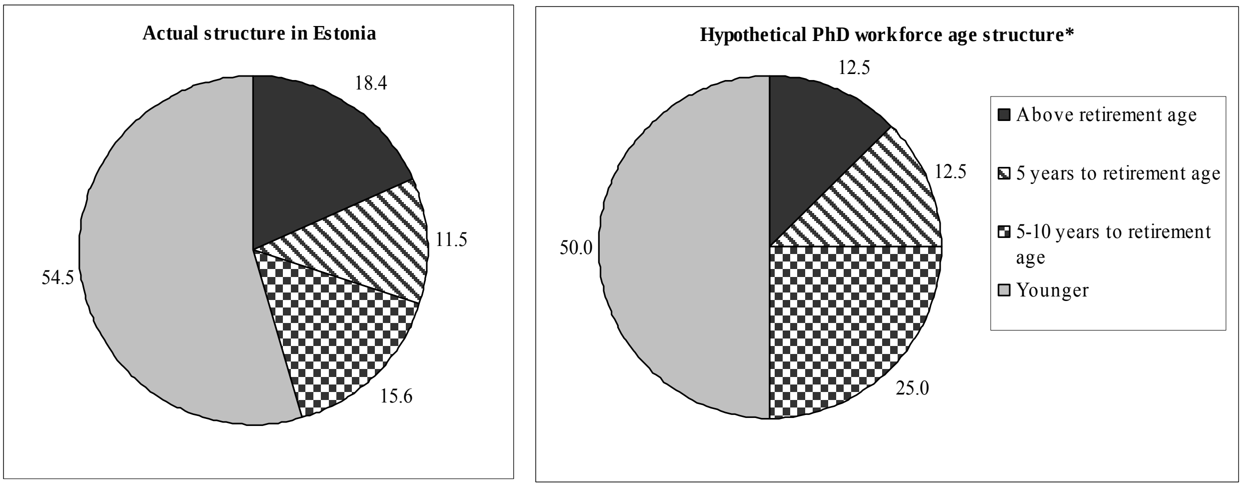

Figure 4 Replacement demand: the age structure of the doctoral workforce

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[37]; 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 4; that is, given these numbers, we would still consider the current age-structure in Estonia as abnormal (because of the higher number of employees above the retirement age). If we consider that there is a net departure of PhDs from academia[38] at some rate, then this would further increase the proportion of PhDs from the younger generations.

Table 9 The age structure of employees with PhD degree by academic fields

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
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

[37] 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. During 1992-2002, the median age for PhD defence was 34 in Estonian universities (Puura *et al*, 2004).
[38] 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.

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	Total
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. 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)[39]. 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).

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 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

[39] 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%).

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 10 reveal that in the next 5 years, about 586 new doctors (up to 40% of the current number) will be needed to replace the doctors currently employed in the academic sector – that makes about 40% of all doctors currently employed. The replacement demand is much higher in institutions of applied higher education compared to universities; 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[40].

As we have already mentioned, the growth 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. Differently, it measures the number of PhDs needed 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 (strategy) 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 (40% of the current number), without funding constraints the number would be 828 (56% of the current number). 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

[40] 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%.

previous estimates for other countries, this is a rather high figure, and the growth demand constitutes a remarkably high proportion of the total demand[41].

Table 10 Replacement, growth and total demand for doctorates on the basis of scientific fields

Indicator	Humanities	Social sciences	Medical sciences	Real- and technical sciences	All fields of education, 2007-11
The current number of employees with a PhD	222	269	209	765	1465
Total hiring in the last 5 years	43%	42%	4%	22%	25%
Replacement demand					
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 replacement demand	28.6%	39.2%	36.3%	44.7%	40.0%
Growth demand					
At actual potential	50.9%	39.8%	10.5%	35.9%	35.4%
Without financial constraints	68.9%	40.5%	33.5%	53.6%	51.1%
Total demand, 2007-11					
At actual potential	79.3%	79.2%	46.9%	80.7%	75.4%
Without financial constraints	97.3%	79.9%	69.9%	98.3%	91.1%
Total demand, per year					
At actual potential	15.9%	15.8%	9.4%	16.1%	15.1%
Without financial constraints	19.5%	16.0%	14.0%	19.7%	18.2%

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.

Summing up both the replacement and growth demand, we can see 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.

[41] 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.

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.

Figure 5 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).

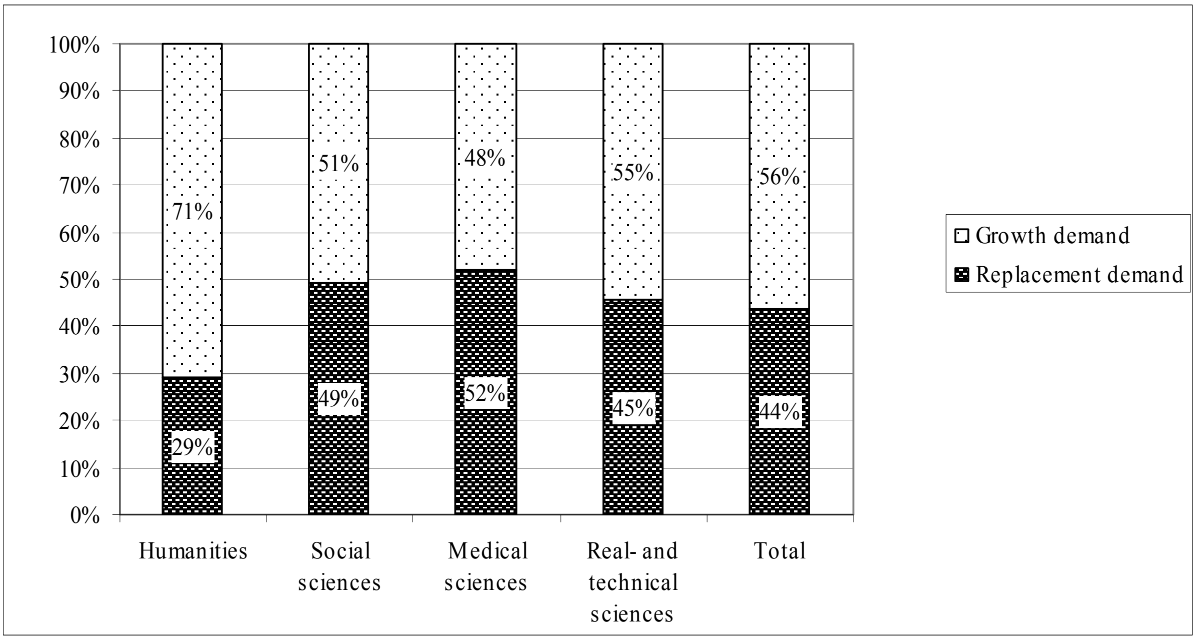

Figure 5. The components of the total demand on the basis of academic fields: relative proportions

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[42].

[42] 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).

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 11, in the state commissioned of schooling 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 order of schooling still corresponds surprisingly well to the demand for PhDs.

Table 11 The breakdown of PhD supply and demand across academic fields, 2005

Academic field	PhD students	New PhD candidates	Graduates	State commissioned schooling	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 6. 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[43], 71% indicated a shortage of funding for surveys, experiments, etc. (Puura *et al*, 2004).

[43] 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.

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. In the past the R&D funding has been reduced as the structural funds opened in 2004 to some extent the national funding of R&D programmes and the national programmes in key areas foreseen in the strategy document Knowledge-based Estonia have not been started (Knowledge Based Estonia 2007-2013). We can also note that the estimated growth demand is quite closely associated to expectations of future research funding: the Spearman correlation coefficient is statistically significant at 0.23. 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.

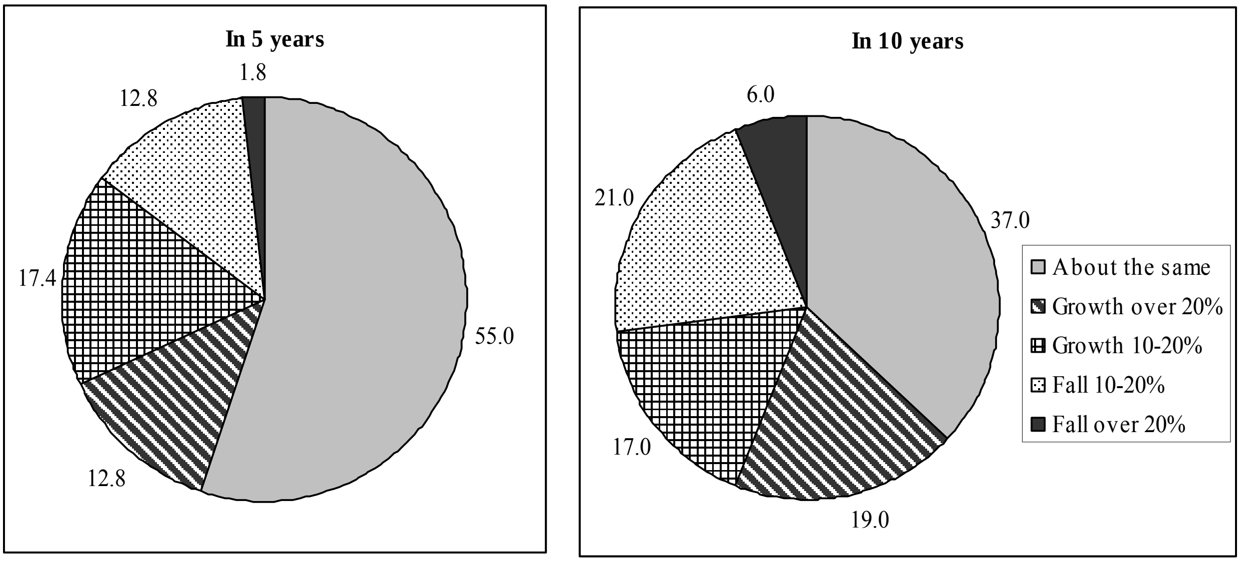

Figure 6 Expectations regarding changes in the volume of research

In order to analyze the reliability of our findings, we hereby also present the correlations between various components of demand in Table 12: these are 1) vacancies, 2) replacement demand, 3) growth demand at actual potential, 4) future growth demand without financial constraints, and 5) the number of additional PhDs needed to achieve the desired percentage of PhDs in total staff. As we can see, vacancies are significantly correlated with future growth demand: this might indicate that vacancies are not completely useless for estimating demand. Replacement and growth demand are correlated with each other, while the number of additional PhDs necessary to increase the proportion of PhDs to the desired level is correlated only with future growth demand without constraints. This evidence should be taken to suggest that the questions in our survey worked at least at a satisfactory level.

Table 12 The correlations between the various components and proxies for the demand for PhDs

	Vacancies	Replacement demand	Future growth demand – with financial constraints	Future growth demand – without financial constraints	Demand based on desired proportion of PhDs
Vacancies	1.00				
Replacement demand	0.14	1.00			
Future growth demand – with financial constraints	0.37***	0.2166**	1		
Future growth demand – without financial constraints	0.44***	0.22**	0.84***	1	
Demand based on desired proportion of PhDs	0.10	-0.03	0.47***	0.20	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 10); that seems to be the reason also for the higher total PhD demand.

Table 13 PhD demand component regressions

Independent variable	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	-0.4261	-0.1985	-0.4261	-0.1304	-0.4599
	(3.76)***	(2.65)***	(3.76)***	(1.66)*	(2.82)***
Research institution	0.1293	-0.0502	0.1293	0.3149	0.1416
	(-0.55)	(-0.24)	(-0.55)	(-1.2)	(-0.27)
Applied higher education institution	0.2778	-0.1618	0.2778	0.344	0.1178
	(-0.74)	(-0.72)	(-0.74)	(2.65)***	(-0.4)
Private	-0.1937	0.0655	-0.1938	0.0451	-0.2498
	(-1.02)	(-0.45)	(-1.02)	(-0.35)	(-1.14)
Medical sciences	0.0723	0.1763	0.0722	-0.0434	-0.0194
	(-0.18)	(-0.7)	(-0.18)	(-0.29)	(-0.05)
Real- and technical sciences	-0.0544	-0.0612	-0.0545	0.2118	0.0792
	(-0.51)	(-0.62)	(-0.51)	(2.30)**	(-0.42)
Research funding will grow	0.4774	0.1643	0.4774	-0.0257	0.4379
	(1.73)*	(-0.85)	(1.73)*	(-0.16)	(-1.11)
Research funding will decrease	0.0556	-0.1011	0.0555	0.0599	-0.1151
	(-0.41)	(-1.05)	(-0.41)	(-0.71)	(-0.73)
Vacancies-to-PhDs	-0.009	0.0002	0.001	-0.0007	0.0014
	(5.22)***	(-0.18)	(-0.6)	(-0.75)	(-0.81)
Desired proportion of PhDs	0.323	0.2159	0.323	0.1027	0.1647
	(-1.61)	(-0.77)	(-1.61)	(-0.66)	(-0.65)
Constant	1.1412	0.6399	1.1412	0.5108	1.9416
	(3.44)***	(1.97)*	(3.44)***	(2.81)***	(4.28)***
Observations	100	95	100	100	91
R-squared	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.

5.2.Public sector

We firstly looked into the positions where the PhD degree is required (or is suggested) in the job description. There were 5 such institutions out of 18 (28%). If instead of the current formal requirement the actual need would be considered, the number of these institutions would be increased further to 8. In total we could identify 124 positions where the PhDs are needed. At the time of the survey only 24 of these (19%) are actually filled with people holding PhD, the rest have masters degree or even bachelor degree or are unfilled. Given that, approximately 100 PhDs are needed to fulfil all these positions. So, if the unsatisfied demand would be satisfied within the 5 years, then that would assumes that in each year about 20 new PhDs are hired. It seems that to large extent the demand will be satisfied with the institutions' current employees obtaining the PhD degree parallel to working.

Concerning expectations on future, .the respondents found in general that the number of positions requiring PhDs should increase – that answer was given by 10 institutions (52%), while 5 institutions expected the need for PhDs to remain at the current level and 3 could not give the answer. There were different reasons that in respondents view could change the demand for PhDs in public sector – these were the changing contents of work, increased knowledge-intensiveness of work, increased share of analytical work, general increase in the activity. We could see that nowadays all ministries aim to create their own competence centres, hire analysts etc. Not all other state institutions are engaged with analytical work; the reasons were the outsourcing of the analytical work (the analysis was bought from outside) or that the analysis is not done due to the profile of the institution. If summing over the positions, we found that the number of positions requiring PhD should increase by 110. That number is slightly higher than the number reported above on the number of PhDs currently at deficit. We took the larger number of the two as the proxy for the future demand.

Due to the low number of PhDs in the public sector we did not collect separately information on replacement demand. If we the replacement demand in the public sector would be proxied with replacement demand due to retirements in the academic sector (33% of the current number of PhDs), then the total demand would be increased to about 135 doctorates.

Most institutions (62%) had also some expectations towards the development of PhD studies. In most cases where there is a demand for PhDs in the institution, the PhDs of some certain field are needed, especially those from social sciences (indicated by 70% of those that required doctorates from certain scientific field). Especially doctorates with degree in economics and law were needed. Concerning specific skills expected from the doctorates, the respondents mentioned analytical skills, broad general knowledge, interdisciplinarity etc, but also it was emphasized that in addition to theoretical knowledge social skills (ability to negotiate, flexibility, ability to work in a team) are needed in order to work as public employees.

The currently low level of PhDs in the public sector (according to our survey 1% of the workforce cf. 0.4% in the total economy cording to census of year 2000) has both supply and demand side reasons. The most common reason indicated by 45% of respondents was the “lack of demand in the public sector”. That reflects also the attitude still present that PhDs are unpractical persons with weak knowledge of the "real life". The other demand-side reasons are the "mismatch to the needs of the public sector" and "relevant are skills, not degree". But there are also supply-side reasons present: the number of PhDs is relatively small and they found employment in the academic sector (24%), lower wage in the public sector (28%), the work in the public sector is not motivating enough or interesting for the PhDs (31%). Going more into details, we can outline the responses like "employers have prejudices towards the employees with academic degree", the Estonian science is far from real life, knowledge-based policy-making is not applied yet, public service is over politicized, academic system does enable PhDs working in public sector to return to academic work. One representative of the ministry claimed that the universities are not eager to perform the applied research that is of interest for the ministries and the ministries do not have any means how to direct the universities research activities in this direction. That might be also reflected on that the share of direct contracts from the ministries in the total research funding is relatively low in Estonia (Masso and Ukrainski 2008). Thus, some of the research and analytical work needed in the public sector could be filled by the academic sector, but that potential is to some extent unused.

Table 14 below summarizes the results. There is difficulty with dividing the demand over various scientific demand. We had information on the currently employed doctorates and in which fields the institutions would need PhDs (many of them did not have any particular preference). Thus, the proportion of growth demand attached to specific academic field was taken as the average of the two.

Table 14**.** The estimated demand for PhDs in the Estonian public sector.

Demand for PhDs	**Humanities**	**Social sciences**	**Medical sciences**	**Real- and technical sciences**	**Field unknown**	**Total**
Current number of PhDs	11	18	13	27	12	81
Replacement demand						
As a percent	20.3	29.4	29.7	38.6	32.8	32.8
Number of people	2.2	5.3	3.9	10.4	3.9	25.7
Growth demand, number of people	15	24	18	37	16	110
Total demand, number of people	17	30	22	47	20	136

5.3. Demand for PhDs in the private sector

In the 1st scenario, the R&D expenditures were modelled as a linear growth trend according to the equation (1), in the 2nd scenario the extensive growth of the R&D expenditures was assumed. Table 15 presents the parameter estimates of the R&D expenditures' and doctorates' equations and Figure 7 depicts the forecasts of R&D expenditures. As we can see, the growth of R&D expenditures is biggest in the secondary sector (29 million EEK per year). In the tertiary sector, additional 1 million kroons of R&D expenditure increases the number of PhDs by 0.32; in the secondary sector the number is 0.14. That is logical given that supposedly the R&D in the secondary sector is more capital-intensive and the R&D in the tertiary sector more human resources intensive. In the non-profit sector the employment of PhDs is rather high despite the relatively low R&D expenditures.

Table 15. The parameter estimated for the R&D expenditures' doctorates equations

	Parameter estimates	
Equation 1 (R&D expenditures)	α_1	β_1
Secondary sector	-19,75	29,15***
Tertiary sector	-8,66	23,31**
Non-profit private sector	-3,95	2,99***
Equation 2 (doctorates)	α_2	β_2
Secondary sector	3,72	0,14**
Tertiary sector	24.80*	0,32***
Non-profit private sector	10,00**	0,66**

Notes. * significant at 10%; ** significant at 5%; *** significant at 1%.

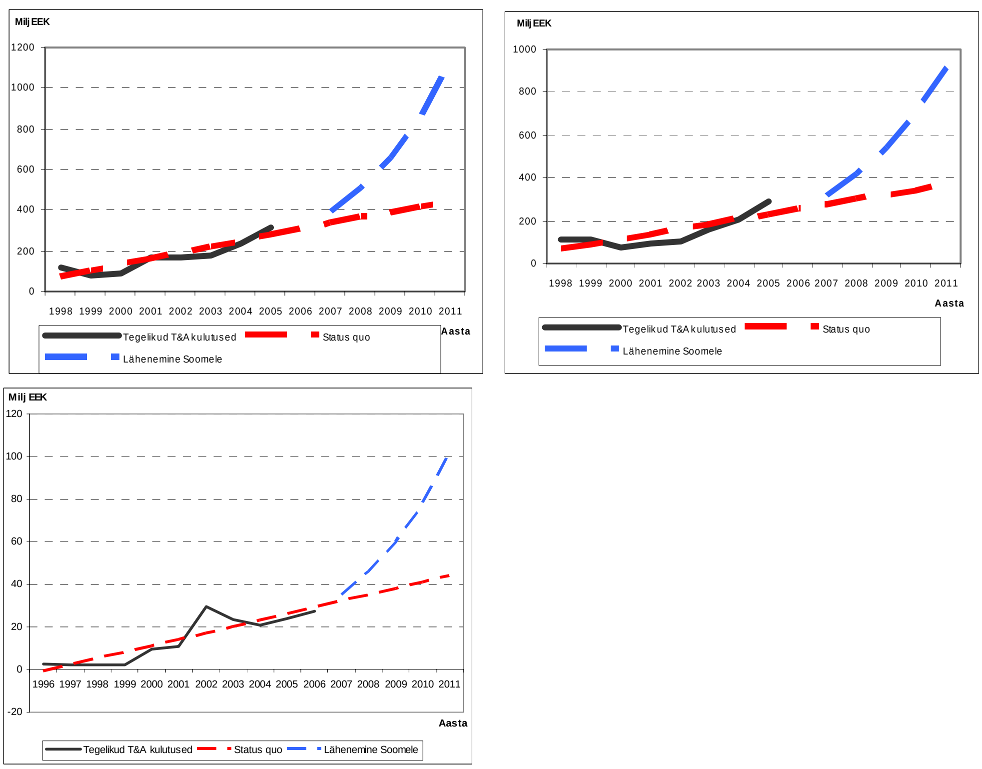

Figure 7 The forecasts for the R&D expenditures of the secondary, tertiary and non-profit private sectors.

The results for the 1st scenario that can be found in Table 16 show that the total demand in the business sector during 2007-2011 is about 123 new PhDs or 25 in each year[44]. The business sector needs the most the PhDs from real and technical sciences (25 PhDs in each year) and social sciences (8 new PhDs in each year), the need for the PhDs in other fields of education is rather limited. Compared to the academic sector, the growth demand is thus smaller in case of humanities and social sciences, and larger in case of real-and technical sciences as well as the medical sciences. As expected, the need in the private sector is significantly below that of the academic sector.

Table 16. The forecast for PhDs in the business sector for 2007-2011 according to the 1st scenario.

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	All fields of education, 2007-11	Total per year
Growth demand	32% (6)	33% (21)	39% (3)	32% (32)	62	12
Replacement demand	20,3% (3)	29,4% (16)	29,7% (3)	38,6% (39)	61	12
Total demand, 2007-11	9	37	6	71	123	25
Total demand, per year	2	8	1	14		

Source: own calculations.

As a second approach, we consider a rapid growth in the amount of R&D expenditure. Such scenario is linked hereby with the model country approach. In case of Estonia, a natural choice for the model country is its geographically and culturally close neighbour Finland. Finland is one of the most developed countries in the world in terms of knowledge-based society; its R&D expenditures as % of GDP (3.5 in 2005) exceed not only those of Estonia (0.94% in 2005), but also countries with high R&D expenditure like Sweden, Japan, USA. In case of Finland also the share of business sector in R&D expenditures is remarkably high (69% in 2005 as compared to 37% in Estonia in 2004; see Figure 8). The Finland has achieved so high position only recently, while in 1995 the R&D expenditure of 2.3% lagged behind Sweden, USA and Japan, then since 1995 the R&D expenditures have grown rapidly. That development is explained with a government programme that involved remarkable additional government R&D expenditure in order to strengthen the national innovation system

[44] It has to be considered that the available data does not take into account whether the doctor is employed full-time or part-time. Thus, we may have overestimated the demand for the PhDs in terms of working hours of full-time equivalent employees. For instance, in 2005 there were 2249 R&D employees in the business sector, but in terms of full time equivalent employees the number was only 1398 (Statistics Estonia, R&D statistics 2005).

and thereby push the growth of economy, entrepreneurship, industry and employment. These government expenditures had also positive impact on private sector R&D expenditures (PhDs in Finland 2003; Eurostat, Science and Technology 2007). Related to the growing funding, during 1991-2001 the number of R&D employees increased twice; the growth was relatively faster in universities and business sector. The proportion of PhDs among R&D employees increased from 8.8% in 1991 to 10.5% in 1993 and remained at the same level till 2001 (PhDs in Finland 2003). Thus, similarly to Finland one option Estonia could consider for increasing the total R&D expenditure is to increase first the public expenditure that will be later hopefully accompanied by increased business sector expenditure. While in 2005 the GDP per capita adjusted for purchasing power was in Finland only 1.8 times higher than in Estonia, the per capita R&D expenditures adjusted for purchasing power were in Finland 786 and in Estonia 105 euros, i.e. the difference was 7.5 times (Eurostat). Also the expenditure per R&D employee was much smaller in Estonia than in Finland (in Finland 3.2% of employees spend 3.5% of GDP, while in Estonia 1.3% of employees spend 0.9% of GDP), thus Estonian R&D employees are bound to have internationally less competitive salaries or poorer research infrastructure.

The bottleneck of the intensive R&D expenditure growth scenario might be the capacity of the private sector to absorb R&D investments, i.e. that investments into R&D bring along in addition to the additional employment of highly qualified professionals and the expensive equipment also solutions supporting the long-term growth of the business sector. The aid of the Spanish government in order to increase the employment of PhDs in the private sector is a good example of the relevance of the capacity to absorb knowledge. Innovations in the form of patents or publications were more frequent in case of PhDs who started to work in the enterprises where there was a previous knowledge-absorptive capacity at the place either in terms of R&D department, previously employed researchers or cooperation with universities or public sector research centres (Cruz-Castro and Sanz-Menendez 2005).

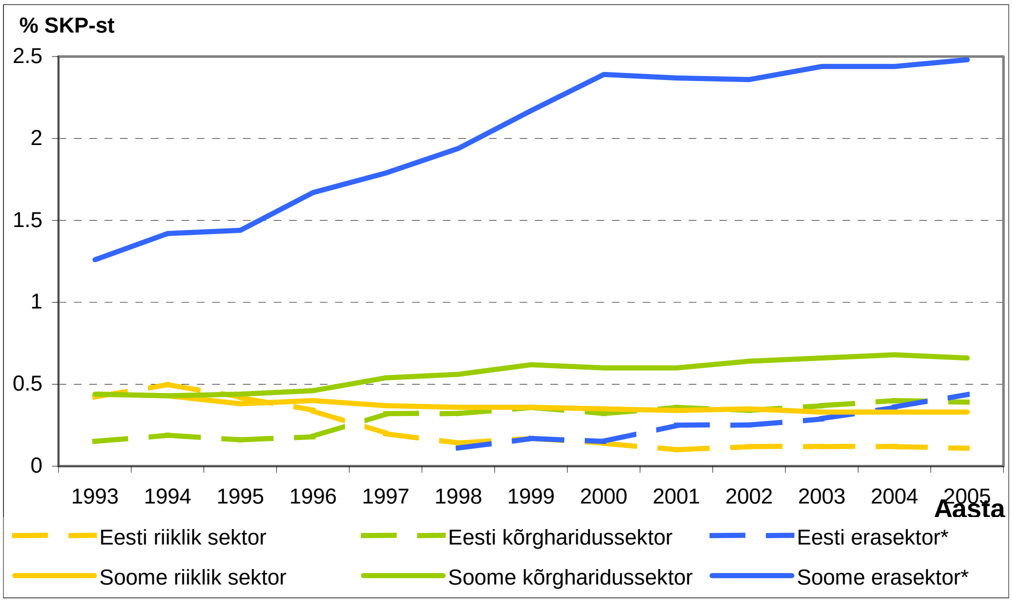

Figure 8. The R&D expenditures of Estonia and Finland as a percentage of GDP (Source: Eurostat).

* - private sector includes both business sector and non-profit private sector expenditure.

According to the 2nd scenario, the real R&D expenditures grows during 2007-2011 30% a year[45]. According to this scenario, the private sector R&D expenditures during 2007-2011 are about 2 times larger than in case of the 1st scenario (respectively 6.7 and 3.7 billion kroons). On the assumption of the 6% annual GDP growth the private sector R&D expenditures will reach by 2011 to the level of 1% of GDP. Thus, Estonian should arrive much closer to the Finnish level of 2.5% of GDP. As the differences between the two countries levels of economic development and R&D spending are quite big, the near-term goal can't be about catching up Finland but rather intensive rapprochement to Finland. That scenario is in compliance with the goal set in the Estonian R&D strategy to increase the business R&D to the level of 1.6% of GDP by 2014 (Teadmistepõhine…2006). If the annual business sector R&D expenditures would continue to grow 30% annually and the GDP grows at 6%, then BERD will reach to the level of 1.87% of GDP in 2011. According to the 1st scenario, the ratio business R&D expenditure to GDP would have remained approximately at the level of 2005 that was 0.42%.

Concerning earlier estimates, Praxis, Advansis Oy, Inno Scandinavia AB (2006) forecasted the growth in the number of R&D full-time equivalent employees in the Estonian

[45] Because at the time of the study the data on R&D expenditure was published till 2005, the numbers for 2006 were forecasted with a linear trend and thereafter similarly the 1st scenario and thereafter a constant 30% growth rate is assumed (see Appendix 3).

manufacturing during 2005-2010. The forecast was based on the assumption that the ratio between the R&D employees and the companies engaging in R&D activities will remain constant in the future, and the rapid growth in the number of firms engaging in R&D experienced during 2000-2005 (from 141 in 2000 to 357 in 2005) can be extrapolated to the future either with linear or exponential trend. Depending on the latter assumption, the number of R&D employees was forecasted to grow either 2 or 3 times, but they also argued these estimates to be rather the minimum given the likely rise of research activities in the future. These estimates are thus closer to our second scenario.

In 2005 state financed 6.8% of the private sector R&D expenditures, 12% was financed by foreign sources and the rest was financed by the private sector itself (Eesti Statistika 2007). The 30% annual growth rate of business R&D expenditure is not achievable without the growing public support towards business R&D, however it is difficult to say how bi the latter should be. Concerning the linkage between the R&D expenditure and employed PhDs, it is assumed that the linear relation estimated for the previous years will continue to hold in the future as well. The results that can be found in Table 17 show that in comparison to the 1st scenario the demand for PhDs is about 3 times higher (87 instead of 25); for the whole 5-year period 436 new PhDs would be needed thus in the private sector.

Table 17.The forecast for PhDs in the business sector for 2007-2011 according to the 2nd scenario.

	Humanities	Social sciences	Medical sciences	Real- and technical sciences	All fields of education, 2007-11	Total per year
Growth demand	195% 33	200% 126	220% 18	199% 198	375	75
Replacement demand	20,3% 3	29,4% 16	29,7% 3	38,6% 39	61	12
Total demand, 2007-11	36	142	21	237	436	87
Total demand, per year	7	29	4	47		

Source: own calculations.

5.4. Comparison of the PhD demand in 3 sectors

Table 17 below summarizes the above analysis by comparing the PhD demand in the academic, public and private sectors. The total demand is even in the most conservative case (assuming the current trends in private R&D expenditures and hiring at realistic opportunities in academic sector) rather high, 80% of the current number of PhDs; in the most optimistic case the percentage would increase to 115%; that means that on the average annually from about 290-400 new PhDs are needed. That would increase the percentage of PhDs in the total employment from around 0.3% to 0.5%. The size of the demand in relative terms is extremely high in the light of earlier studies. That is explained to large extent by the high replacement demand that can be considered to be a kind of backlog demand, i.e. the accumulating difference between demand and supply in the past due to the insufficient replacement of ageing workforce Still, the growth demand is even higher. While public R&D spending should also increase rapidly in the future in order to reach the targets set in R&D strategy that is balanced with the decreasing number of students. In academic sector the strong growth demand reflects in our opinion very much the backlog demand (the accumulated unsatisfied demand in the past).

Table 18 Comparison of the demand for PhDs

The kind of demand	Academic sector: Hiring with actual potential	Academic sector: Hiring without financial constraints'	Public sector	Private sector: 1st scenario	Private sector: 2nd scenario	Total of all sectors
Current number of PhDs	1465	1465	81	190	188	1736
Incl. Humanities	222	222	13	19	17	254
Social sciences	269	269	21	64	63	354
Medical sciences	209	209	15	8	8	232
Real- and technical sciences	765	765	32	100	99	897
Replacement demand, % of current number	40.0%	40.0%	32.8%	32.1%	32.5%	38.8%
Growth demand, % of current number	56.5%	56.5%	135.8%	32.6%	199.9%	57.6%
Total demand, % of current number of PhDs	96.5%	96.5%	168.6%	64.7%	232.4%	96.4%
Incl. Humanities	82.7%	103.9%	156.1%	52.3%	215.3%	102.7%
Social sciences	99.8%	102.8%	165.2%	62.4%	229.4%	99.3%
Medical sciences	46.8%	69.8%	165.5%	68.7%	249.7%	76.1%
Real- and technical sciences	77.0%	94.9%	174.4%	70.6%	237.6%	95.0%

Note. The total demand calculated over all sectors is based on the demand of academic sector considering actual hiring potential and the 1st scenario in case of private sector.

Shortly, we think the most important reasons for that were on the one hand the unadequately low supply of new PhDs connected to the higher education reforms (Kristapsons et al. 2003), relatively low salaries for researchers compared to the much more attractive employment opportunities outside the academia, low levels of research funding, funding system based on past performance not favouring the new entrants (Masso and Ukrainski 2008). During 1991-2001 the number of researchers with PhD decreased by 30% in Estonia (Kristapsons et al. 2003). The reason is also the internal brain drain (mobility to commercial and governmental structures) as well as external brain drain (mobility to abroad) – the available data seems to suggest that while leaving the country was important (about 500 people from the Academy of Sciences left during 1989-1993), starting the work in public administration and private sectors was much more important (Kristapsons et al. 2003).

In the public and private sectors the situation is different connected to the initially low number of PhDs; because of that replacement demand plays a relatively smaller role compared to the academic sector. Also because replacement demand in the public and private sector was approximated with replacement due to retirements in the academic sector, the growth demand is cause for differences in the total PhD demand in 3 sectors. The demand is extremely high in the public sector, owing to its rather low level. In the private sector, the demand depends critically on the assumed dynamics of R&D expenditures, while in case of the continuation of the past trends the demand is below that of the academic sector, in case of extensive growth of R&D expenditures (to the level of 1.87% of GDP in 2011) the demand in relative term is the highest in the private sector. The total demand would be distributed between the 3 sectors depending on assumptions and scenarios according to the following proportions: 70-80% in the academic sector, 7-10% in the public sector, 10-20% in the private sector. Given that the proportions of current employment are respectively 84%, 5% and 11%, the development of PhD studies should consider these changing proportions so that (some) of the PhD candidates are better prepared for the work outside the academic sector. Of course, all of these estimates are imprecise and can be criticized from different angels, but the qualitative results are in our opinion quite clear. The total demand divided over 5 years (280-400 new PhDs per year) is relatively close to the figure of 300 that is the expert estimate suggested by the Ministry of Education and Research and is also the written down in the national policy documents. Concerning earlier expert estimates, Tiits and Kaarli (2002) argued that about 80 PhDs are needed to ensure the continuity of research and education; considering also the needs of public sector and knowledge intensive enterprises, the number would increase even to 200. While we agree on that public and private sector are increasingly important for PhD demand, according to our estimates still the academic sector remains the most important employer.

One other conclusion is that the needs of the private and public sector influence the structure of demand across various scientific disciplines. Compared to academic sector, in public sector the demand is relatively higher for social sciences (respectively 20-26% and 32% of total PhD demand) and lower for humanities and medical sciences. In the private sector the demand is marginally higher for real- and technical sciences; that follows from our modelling assumptions (it was assumed that the current structure of the workforce is retained), however for R&D like product development probably much more individuals from engineering and technical subjects are needed. Thus, in the future the structure of the state order of schooling should consider much more the needs of the private and public sector.

6. Conclusions and implications

The aim of the current paper was to estimate the need for new PhDs in the Estonian academic sector (higher education sector and research institutes), public sector (ministries, state agencies) and business sector over the 5-year period 2007–2012. For the first two sectors the demand was estimated from surveys undertaken among employers, while the private sector demand was estimated from a model that assumed the PhD demand to be determined by the amount of private sector expenditures on R&D. Two scenarios were constructed, one based on the continuation of the past trends in the business R&D spending and the other one assuming the business R&D to reach the level of 1% of GDP by year 2011. As with earlier studies, we distinguished between the replacement demand (the demand resulting from the need replace PhDs leaving due to retirements, deaths and net movements between different 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 in all 3 sectors. 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 Estonia. 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. As expected, most of the demand for PhDs (70-80%) is coming from the academic sector and just 7-10% from the public and 10-20% from the private sector, still the to last sectors are in the future increasingly important places of employment for PhD. The shortage of PhDs in the academic labour market is evidenced also by other indicators the high proportion of vacancies, low proportion of positions filled via actual competition between applicants and the undesirably low proportion of PhDs in the total the total research and teaching staff.

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 in academic sector expected that funding would remain at its current level. But the high future demand is in our opinion very much related to the backlog demand, i.e. unsatisfied demand that has accumulated over the past years since the beginning of 90s.

Thus, according to our estimations, the total demand for PhDs (the sum of the growth and replacement demand) in all three sectors together will be in the range of 1400–2000 persons during 2007-2011. Such a need corresponds to the 290 to 400 PhD defences each year (about 17-23 % of the current number of PhDs employed) - for comparison, the total number of PhD defences in Estonian universities in 2006 was 140. Thus, the total annual demand for new PhDs in all three sectors is 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[46]. XXX 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 following economic slowdown. 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.[47] If the compensation for the scientific workforce was at an internationally competitive level, the international mobility of PhDs could solve the current shortage[48]. International mobility is

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[46] 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.

[47] 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).

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

therefore an important tool. At the same time it is also important to enhance the mobility between different sectors. One policy measure to enhance the knowledge exchange between sectors is the grants paid to business firms that employ new graduates of PhD programmes; such scheme was applied successfully for instance in Spain. 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.

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.

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