Support for Evolution in the Knowledge-Based Economy: Demand for PhDs in Estonia

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Abstract

The doctoral workforce globally constitutes a rather small segment of the labour market. However, PhDs provide crucial input for educational and R&D activities, traditionally through employment in academia, and nowadays increasingly in the public and private sectors. This paper aims to estimate the need for new PhDs in the Estonian academic, public, and private sectors for the period 2007-2012. Need in the academic and public sectors is estimated by a survey of employers (e.g. universities, research institutes, ministries); private sector need is derived from forecasted R&D expenditure in the business sector. Results show that expected demand for PhDs is significantly lower in the public and private sectors than in academia. Total demand over all three sectors is rather high, annually more than 10% of the number of PhDs, caused both by high replacement demand from upcoming retirements and by growth demand. The policy implication of our results is that planned increase in PhDs should correspond with other developments in educational and R&D policy.

JEL Classification: I2, J4, 03
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1. Introduction

Both the aims of the Lisbon strategy and development plans for EU Member States (including Estonia) emphasize a move towards a knowledge-based and innovative economy. This suggests that the role of science in the organization of society is becoming increasingly important. Individuals with academic degrees are needed both in public and private sector institutions that undertake analytical work (including, for instance, economic analysis or environmental impact assessment) because possession of a PhD implies command of the analytical tools of the respective area.

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Demand for PhDs[2] thus originates from the academic, public and private sectors. Earlier statistics and studies show that most graduates of PhD programmes start working in the academic sector[3] , with medical specialists an exception[4] . Similarly, in Estonia most PhDs engaged in research and development ("R&D") are employed in higher education (83% in 2006). Another 9% were employed in the state sector but only 8% in the private sector[5] . This is also reflected in a 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).

Although PhDs are of crucial importance for research and higher education, demand for them is hard to predict precisely, because many influential factors (e.g. educational and R&D policy decisions, technological changes) are either hard to forecast or fundamentally unpredictable. Balancing PhD supply and demand might be complicated due to the long period needed to obtain a PhD degree, which complicates arranging supply to meet demand. Shortage of staff with doctoral degrees may adversely affect teaching quality and, 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, while increased retirement age can also have a negative impact (Basil and Basil, 2006).

This paper aims to estimate need for new PhDs in the Estonian academic, public, and private sectors over the five-year period 2007-2012. Given the period of the forecast, the situation has changed considerably by the time of publication of this article (2009) due to the economic downturn caused by the international financial crisis. (The resulting lower ability of state to fund higher education and R&D is a factor that can not be overlooked in future demand for PhDs; however, we believe that the study still gives much adequate information on factors influencing PhD demand. We believe that, based on previous studies, total demand for PhDs can be divided into three basic components – firstly, R&D institutions and higher education institutions in both 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. While PhDs in all countries are predominantly employed in the academia and far fewer elsewhere, the latter proportion is increasing (Cruz-Castro and Sanz-Menendez 2005). PhDs in the private sector are important for ensuring innovation in the economy and for knowledge transfer from academia to the private sector: in particular, tacit knowledge can spread in this way if after graduation PhD students start working in the private sector (Mangematin and Robin 2003).

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[2] PhDs 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. While in Estonia graduates of the 6th level of ISCED97 are all PhDs, for other EU countries this need not be so (Eurostat 2007). In the category of PhDs, we included all those with a doctoral or other academic degree assigned equivalent status. In our case, the latter included mostly those with a candidate degree (in Estonian: teaduste kandidaat; in Russian: kandidat nauk) which was given in the Soviet Union and is nowadays officially recognized as equal to a PhD.

[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 (PhDs in Finland…2003; McKenzie 2007).

[4] Often the academic sector has been classified under the public sector; similarly, most medical workers belong to the public sector (local government).

[5] Source: Statistics Estonia, R&D statistics.

Demand for PhDs may come either from the need to replace faculty leaving for retirement or other reasons, or the growing level of employment of PhDs. Our estimates of demand in the academic and public sectors are based on a survey of employers, such as universities, institutions of applied higher education, research institutes, ministries, and government agencies. Demand in the private sector is estimated with a structural model from forecast dynamics of R&D expenditure. Our contribution to the literature is that while existing studies seem to be exclusively in highly developed countries, little information exists 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 current low levels of R&D expenditure and restructure their economies in order to sustain competitiveness in the context of a vanishing low labour cost advantage. Estonia is especially interesting – the R&D system is on the one hand very small with total R&D expenditure in 2006 at just 150 million Euros, but its growth rate has recently been one of the highest in the EU (45% increase from 2005 to 2006, only below that of Latvia). Estonia has a highly concentrated academic sector with the largest institution, the University of Tartu, accounting for some 50% of total research funding, 60% of PhD graduates (2005) and over 50% of the articles in the ISI Web of Science. We estimate whether targets set in Estonian national policy documents for PhD defences match the actual needs of the academic sector.

The rest of the paper is structured as follows. The following section reviews existing literature on demand for PhDs. The third section provides background information 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 demand for PhDs

Studies of future demand for PhDs and the imbalance in supply and demand started in the 1950s in the US (Forecasting demand…2000) and the UK (Godin, 2002). Despite discussions over several decades, so far no consensus exists on an appropriate methodological approach to the problem, so that study methods vary from econometric models to interviews, questionnaires, benchmarking with other countries, and informal discussions of factors affecting PhD supply and demand. Considering the huge variety of fields within the scientific sphere and the breadth of the labour market for PhDs, most studies concentrate either on particular fields[6] or on a particular segment of the labour market – public, private, or academic. The latter is central in most studies, as the highest concentration of PhDs occurs there. Many studies have also focused more broadly on the category of scientists and engineers or total staff working on R&D instead of singling out PhDs. Finally, other studies have focused on other aspects of the academic or PhD labour markets[7].

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[6] The most common fields addressed have been economics (Cartter, 1971, Hansen et al, 1980), business administration (accounting – Campbell et al, 1990; marketing – Basil and Basil, 2006), engineering and science (Freeman et al. 2000).

[7] E.g. the labour market for young scientists (see Recotillet (2003) for databases and research in Europe on that topic), young scientist entry to the labour market shortly after graduation (like the "What Do PhDs Do" study in the UK, UK GRAD Programme (2006)) , international mobility of highly qualified labour and influencing factors (see Brain Drain – Brain Gain (2002) for Germany; and Auriol (2007) for an international comparison of OECD countries).

The motivation for many studies is the possible undersupply of PhDs, with most studies discussing a potential deficit rather than overproduction of PhDs. It has been found that the US labour market for PhDs is characterized by huge fluctuations and imbalances of supply and demand. One explanation could be that the long period needed to obtain a PhD degree may lead to varying spells of over-supply and undersupply (Braddock 1992)[8] , but it has also been argued that production of PhDs might be a financial loss for schools (Basil and Basil, 2006). Overproduction of PhDs may result from many students starting PhD studies on the basis of expectations of a high number of future available academic positions (as happened in the US in the 1980s), universities employing PhD students even if no matching demand exists in the labour market as they create additional value for the faculty by research and other obligations (Jones, 2002-03) and because producing PhDs might help stimulate further demand for research (McIver Consulting, 2004). Both under- and oversupply might be costly.

Forecasting in this market is not easy. While some factors are relatively easy to predict (e.g. demographic changes), others such as future technological changes are quite difficult to predict Forecasting demand…2000. Leslie and Oaxaca (1993) conclude that the literature seems to imply that forecasting models are of questionable value in the longer term, so that it is necessary to understand the factors behind supply and demand for scientists and engineers. Moreover, there are no forecasts, but rather projections[9]. Often, relative shortage or oversupply are analyzed using indicators such as relative wages, vacancies, unemployment rates, or field of employment (Borthwick and Murphy, 1998); PhDs in Finland… 2003.

In academia, PhD demand results mainly from retirements and from developments in research and higher education financing by the public and private sectors. Thus, most studies distinguish between replacement demand and growth demand. The first includes new PhDs to replace retirements, deaths, and net movements between academia and other jobs. Results of different studies show that the most significant component of replacement demand results from the need to replace retirements; demand to replace deaths and net movements between academia and other jobs forms a rather modest share (Campbell et al. 1990). 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 (affecting growth of number of students, Cartter 1966), availability of research grants, wages, different costs (Hansen et al. 1980), 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. Many studies have not considered the backlog of demand that results when, at some point, a shortage of labour force emerges, meaning that demand exceeds supply cumulatively so that gaining a balance takes more time. Similarly, a supply backlog might arise if 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 private sector share is growing. Here, PhDs are first of all needed in R&D; however, mobility

[8] Several other studies suggest that the labour market for scientists and engineers operates like the normal labour market in the sense that when a deficit or overproduction occurs, market forces are able to draw back the system to a near balanced condition (Brown, 1993).

[9] Predictions conditional on assumptions regarding future economic and labour market conditions.

between science and industry is also important, and not only their employment level at some point[10]. Briefly, modelling business sector demand for PhDs follows one of four approaches.

- Structural modelling: by comparing demand and supply of PhDs the volume of growth demand, replacement demand and supply are calculated; see e.g. Marey et al. (2001) for science and technology graduates of the EU14 countries. Bosworth (1981) for demand for qualified scientists and engineers in UK manufacturing industry; Mc-Iver Consulting (2004) for estimates of PhD and non PhD R&D employees in Irish business. This approach is the most demanding with respect to the necessary data.
- Asking employers (universities, government agencies, private firms) for their opinion on PhD growth and replacement demand (see e.g. Freeman et al. 2000; Shawver, 1973; PhDs in Finland… 2003). The advantage of these methods is their consideration of real situations and future trends since individuals working in the field routinely have the best insight into the matter. These methods have been criticized for not revealing reasons behind firms' decisions, and lack of information on sensitivity of demand within firms towards changes in economic conditions (Bosworth, 1981).
- Benchmarking by using some other country as a desired target for future developments. The respective indexes or employment/graduation coefficients are then projected for the country under observation. The advantage of this approach is smaller data requirements and the opportunity to learn from the experience of other countries, while the limitation is that no two countries are identical.
- Estimates based on performance of PhDs in the labour market: relatively high wages or very low unemployment might indicate their absence in the economy. High numbers of PhDs in the labour market and in post-doctoral positions have been seen as an indication of the difficulty of finding jobs, though these indicators can be interpreted in several subjective ways (Jones, 2002-03).

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

In this section, we review the position of PhDs in the Estonian labour market in international comparison. As in other countries, PhDs constitute a rather small proportion of the total workforce (see also Table 1). According to the 2000 census[11], the 25-64 age group contained 1,906 persons with a PhD or equivalent degree, or 2.7 PhDs per thousand. That is a relatively low number compared to countries like the US (8.4), Canada (6.5), or Germany (15.4) (Auriol 2007). In the total population, 2,833 persons held a PhD or equivalent degree, i.e. 0.21% of total population. In Finland the corresponding number in 2000 was 0.27% and 0.35% in 2004 (Statistics Finland 2007, Eurostat 2007). Estonian numbers are close to those of its Baltic neighbour Latvia. Among total R&D personnel,

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[10] For knowledge and skills to be transferable between the academic and industrial sphere, people also need to be mobile. Some knowledge (so-called tacit knowledge, cf. codified knowledge) is always attached to individuals through their competences and experience. Therefore, location and mobility of competence become vital in analyses of technology transfer, especially between universities and business (Lanciano-Morandat and Nohara 2004). The positions of PhD holders in firms give vital information about what types of knowledge obtained in universities are applied and which university-industry networks are created (Sumell et al., 2005).

[11] Exact numbers on PhD employment rates, unemployment rates, and other indicators are available from the 2000 census, while for later years estimates from other databases such as labour force surveys are rather imprecise due to the small number of PhDs in most survey samples.

the proportion of PhDs in the higher education sector was 41%, while in the state sector only 7%. This indicates that on the basis of the same total R&D expenditure at the aggregate level, a higher share in business R&D implies a lower need for PhDs.

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

	Estonia	USA	Germany	Portugal	Latvia
	2000	2003	2003	2004	2007
Number of PhDs surveyed	2833				3603
Share of PhDs in population (%)	0.21	0.84	1.54	0.21	0.16
PhD inactivity rate* (%)	20.09	11.1	22.7	6.6	
Inactivity rate* (%)	40.86	21.0	41.9	34.9	
PhD employment rate* (%)	78.96	86.3	74.8	91.1	95.5
Employment rate* (%)	51.1	74.8	52.4	61.7	62.0
PhD unemployment rate* (%)	1.19	2.9	3.2	2.5	
Unemployment rate* (%)	13.6	5.3	9.8	5.2	
PhDs working in R&D	1894				

Source: Statistics Estonia, Auriol (2007); Central Statistical Bureau of Latvia.
Notes: For Estonia, the numbers are for population 15 years and older; for other countries, 25 years and older. In Latvia, the survey involved PhD holders aged 70 and younger.

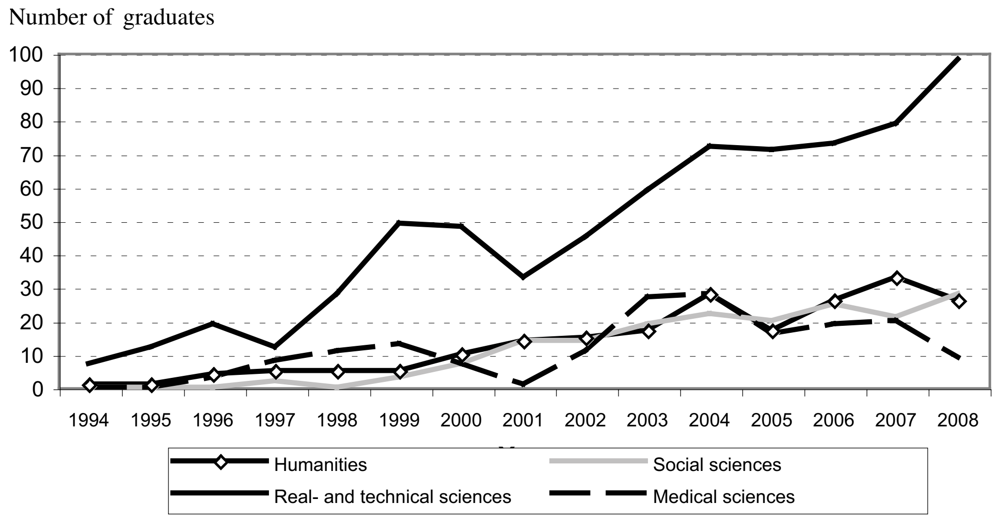
The unemployment rate for PhDs was remarkably low compared to other educational levels. While the general level for unemployment was 13.9%, among those with a higher education, 5.1%, among those with a masters degree it was 1.9% and among PhDs a mere 1.2% in 2000. This indicates good performance of PhDs on the labour market. It has also been observed elsewhere that unemployment among PhDs is much lower compared to national averages; however, Estonian numbers are also low compared with international figures[12]. 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). 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 cannot 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. In 2000, PhDs constituted about 0.4% of the total workforce in Estonia; as to other countries, the percentage was 1% in the US, 2.8% in Switzerland, and 2% in Germany (Auriol, 2007). PhDs were employed mostly in education (45%), R&D (20%) and public services (17%, including medical services). The non-R&D business sector employed 17% of PhDs. These facts plus some anecdotal evidence from other post-Soviet countries tell us that due to low wages many promising PhD holders have left academia and

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

moved to the private sector. Given also the relatively low share of business R&D, the high proportion of PhDs in the business sector is thus for reasons other than business R&D involvement.

Another important indicator of PhD performance on the labour market is salaries. Rõõm (2007) concluded that no benefits are apparent from acquiring a PhD after a master's degree, i.e. while two years of master's studies increase salary by 39%, then six additional years in master's and PhD programmes increase salary only by 36%. When other control variables are considered (academic field, sector of employment), salaries of masters are 22% lower than those of PhDs. Thus, it seems that PhD degrees are obtained in fields where salaries are lower (humanities, arts) and they work in sectors with lower salaries (education). As to international mobility of the PhD workforce, Murakas et al. (2007) found from a survey among scientists, instructors, and PhD students that the Estonian scientific environment is characterized in international comparison by poorer remuneration, infrastructure and qualifications. On the positive side, better possibilities for an academic career were indicated.

A growth trend has occurred in the number of PhD defences during 1995-2006: from 14 in 1995 to 143 in 2006[13] (see also Figure 1). A constant growth trend is visible in all fields, while developments are most unstable in medical sciences. The number of new students entering PhD programs increased from 250 in 1995 to 370 in 2000 and 444 in 2006. Of these, 50% (2004) were financed by the Ministry of Education and Research; other places were funded by universities themselves (Statistical Office of Estonia; Ministry of Education and Research). The latter point appears to indicate that universities perceive a shortage of PhDs and are trying to solve the problem by increasing the number of PhD candidates accepted.



Source: Statistics Estonia

Figure 1. Number of graduates in PhD programmes (ISCED6 level)

[13] Numbers reported for resident graduates have been excluded from numbers of new PhDs.

Total employment of PhDs is connected to total R&D expenditure. Total R&D spending as a percentage of GDP was 1.15% in Estonia in 2006. This exceeds the average of the 10 new Member States (0.91%), but lags behind the EU average (EU15 1.91%, EU27 1.84%). National policy documents have set a target for 2014 at 3% (Knowledge Based Estonia 2007–2013). The increase in total R&D spending in recent years (from 0.6% of GDP in 2000 to 1.15% in 2006) has occurred partly thanks to access to EU structural funds in Estonia since 2004. However, increases in government expenditure have remained significantly below the national policy target (Reid, Walendowski, 2006)[14] . Although the proportion of business R&D in total R&D is growing (in 2000 24%, in 2006 38%), it is still much lower than the EU15 average (54.8% in 2005). Compared to R&D, 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 against the EU-25 average of 1.15%. Again, neighbouring Sweden and Finland are far ahead (in Finland 2.05%, in Sweden 2.16% of GDP).

Future demand for PhDs in the education sector is set to decrease due to an expected drop in student numbers following demographic trends; though an ageing population is visible in all developed countries, the changes are especially sharp in the Baltic States (Schlitte, Stiller 2007). A sharp drop in student numbers is expected because the sharp drop in birth rates at the beginning of the 90's will soon be reflected in the 16–18 age group, forecast to decrease from 64 000 in 2003, to 44 000 in 2010, and 33 000 in 2015 (PRAXIS 2003). Still a few more years are needed before the impact is visible on university student numbers, when many academic staff may need to move from teaching to research to preserve their employment.

4. Method and data

Total PhD demand consists of replacement and growth demand. The first reflects replacement of PhDs currently employed; that is, how many new PhDs are needed in order to keep the number of PhDs employed at the current level. Growth demand indicates necessary growth in the total number of PhDs due to enlargement of the sector, e.g. based on number of students, R&D volume, and the desired proportion of PhDs among all instructors and scientific workers. While growth demand and total demand could be either positive or negative, replacement demand is defined as non-negative. Thus, if leavers are not replaced by new personnel, a positive replacement demand exists, offset by negative growth demand, resulting in zero total demand (Shapiro 2001). Replacement demand according to our approach is due to retirements and mobility of employees to other sectors[15] or abroad.

We estimate growth and replacement demand of PhDs in the academic and public sector by surveying employers. Growth demand of PhDs in the private sector is projected based on business sector R&D expenditure forecasts. Replacement demand of PhDs in the private

[14] Reasons might be that EU structural funds replaced Estonian government funding; national technology programmes in key sectors have not been launched; financing has been based on results of annual negotiations instead of following targets set in R&D strategy (Knowledge Based Estonia 2007-2013, 2006).

[15] In general the mobility of PhDs between the academic and private sectors is rather low. Cruz-Castro and Sanz-Menéndez (2005) found from a survey of PhDs in Spain that once the academic or private sector has been chosen for employment, the person will stay there for longer.

sector is equalled to that of the academic and public sectors. Analysis occurs across four scientific fields: social (No. 1 and 3 in ISCED97), humanities (No. 2 in ISCED97), real and technical (No. 4, 5, 6 and 8 in ISCED97), and medical (No. 7 in ISCED97). This distribution is in line with classifiers of scientific disciplines (Frascati Manual 2002, 2002).

The advantage of a survey for assessing future labour demand is that employers that are actually hiring PhDs possess inside information about e.g. developments within the sector, future trends, or potential student numbers. The negative side of such a survey is that quality of answers depends on who responds. This point mostly concerns small private academic institutions. The Estonian demographic situation is worsening so that student numbers will decline in the future, but many private schools did not see this as a problem; moreover, they did not plan any increase in research at the same time. But they all saw an increase in demand for PhD holders. Another possible factor affecting survey results might be self-selection: institutions that suffer the greatest shortage of PhDs might also be more willing to respond than those that do not need (or do not want) to hire additional PhDs (Basil and Basil, 2006).

A survey of the academic sector was undertaken in the spring of 2006, a survey of the public sector in the spring of 2007. At first the questionnaire was sent to respondents by e-mail. In the second phase the survey continued by face-to-face interview, if necessary, in the academic sector and by telephone interview in the public sector. The questionnaire consisted mostly of multiple choice questions, with a few open-ended questions added. 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. Growth demand was estimated by asking institutions how many new PhDs they would be ready to recruit assuming sufficient financial resources. The alternative option would be to look at unfilled positions or vacancies (e.g. Basil and Basil (2006) used job advertisement data). Experience shows that without a financial guarantee, vacant positions are not maintained. To some extent the logic of vacant positions works in the case of professorships, simply because no appropriately qualified individuals are available.

In the academic sector, 115 structural units were interviewed including 20 R&D institutions and 95 higher education institutions. Of these only 10 were private academic institutions (or their subdivisions). We left aside administrative departments of higher education and research institutions, funding agencies (like the Estonian Science Foundation), scientific libraries and the Estonian Academy of Sciences. Total research and teaching staff in these institutions was 3523, including 1465 PhDs. According to data from Statistics Estonia, our survey covered about 77% of all PhDs working in higher education institutions or R&D establishments.

In academic institutions surveyed, on average 44% of all positions were filled by PhDs (Table 2)[16]. The lower the position, the lower the proportion of positions filled by PhDs; this stems from the logic of positions in higher education and research institutions. As expected, the proportion of PhDs is high among full professors (84%) and docents (associate professors) (79%); as a rule, a PhD is required for these positions. The humanities are an exception

[16] As to other countries, in Finland PhDs were estimated to account for 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).

(only 56% of all professors hold a doctoral degree), because in the case of some fields in the humanities (creative specialities) a professorship could also be filled by a creative person who has achieved international recognition. The proportion of PhDs is, as expected, lower in institutions of applied higher education (12.3%) compared to universities (49.4%). In a study in polytechnics in Finland, just 5.2% of full-time teaching staff had a PhD (PhDs in Finland…2003). Strikingly, in institutions of applied higher education, the number of docents and professors that lack a PhD is not negligible (and not just in the humanities).

Table 2. Relative importance of PhDs in various positions in educational institutions

Position	Humanities	Social sciences	Medical sciences	Real and technical sciences	Total
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

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

In the case of public sector institutions (ministries, agencies, inspections, foundations, bodies governed by public law), these were divided into three groups. Firstly, institutions that according to available information engage in analytical work (indicated e.g. by the presence of analytical departments or jobs) were surveyed with a longer version of the questionnaire. Secondly, institutions with limited engagement in analytical work were surveyed by using a shorter version of the questionnaire. Thirdly, institutions that in our opinion had no need for PhDs were left out of the analysis. In the public sector, 55 institutions received the questionnaire, 29 questionnaires were received back, a response rate of 53%. The institutions surveyed had altogether 7541 employees, of whom 81 or 1% had a PhD degree. The survey thus covered about 20% of employees working in the "Public administration and national defence" sector. At least one person with a PhD was employed in 19 institutions out of 29. The proportion of PhDs was highest in the Ministry of Education and Research (7%) and the State Medicines Agency (6.8%). PhDs worked more often (in 80% of cases) as analysts, professionals, middle managers, or counsellors. Four out of 17 institutions had positions requiring a PhD in the job description. Among PhDs, 14% had a degree in humanities, 22% in social sciences, 16% in medicine, 33% in real and technical sciences, while degree details are unknown for the rest (17%).

In the private sector we considered questioning employers an inappropriate approach because the business sector employs only 10% of all PhDs and these few are scattered across industries, making them difficult to survey. In addition, many employers might not understand the content of a PhD degree and so are unable adequately to forecast demand for PhDs. Thus we used the structural approach to modelling PhD demand based on the Statistics Estonia R&D survey and to a lesser extent on the Estonian Labour Force Survey ("LFS") data. The problem of R&D statistics collected annually by Statistics Estonia is the relatively short time series (eight years) which does not enable compilation of a more sophisticated econometric analysis. Comparison of Estonian census data and R&D statistics reveals that in 2000 85%

of PhDs employed in Estonia worked in research and development. Thus the R&D database covers a large proportion of Estonian PhDs in the private sector.

In structural modelling, the approach of Marey et al. (2001) was followed to a large extent. Firstly, in modelling growth demand we made strong assumptions: that the private sector only needs PhDs in R&D, and secondly that the need for PhDs is determined by the amount of R&D investment. We modelled need in three sectors: the secondary sector in pursuit of profits, the tertiary sector in pursuit of profits, and a non-profit private sector. In this sector there were no R&D employees with PhD. The primary sector was excluded from analysis as during 1998-2005 and R&D investment in this sector was very low. Replacement demand was based on replacement rates for the academic sector. Future R&D investment in each sector was assumed to follow the past eight years' average real growth rates. The relation between R&D expenditure and personnel with a PhD was modelled by simple OLS regression separately for each sector. Based on the R&D expenditure forecast, sector demand for PhDs was projected assuming the linear relation between R&D expenditure and personnel with a PhD continues to hold. Finally, the forecast total number of private sector PhDs was allocated between the four fields of education. In the non-profit private sector, data on distribution of scientists and engineers with PhDs across fields of education was taken from national R&D statistics; in the business sector those data were not available, so that data from Estonian LFS on distribution of professional occupations by fields of education were used instead. We assumed that distribution of private sector PhDs across fields of education stays constant during the period of forecast.

5. Results

5.1. Academic sector

We start with presentation of results from academia; as expected, most PhD demand comes from this sector, so that the situation here also affects other sectors – e.g. a large shortage in academia might suggest difficulty in satisfying public and private sector needs. We start the analysis from vacant positions (see Table 3) which may show the presence of unsatisfied demand. Unfilled positions exist in about 60% of institutions or subdivisions. In terms of vacancies, shortage of PhDs is greatest in the social sciences and least in medicine. Total vacancies constitute a rather high proportion (20%) of total PhD numbers. The number of vacancies indicates actual current need for PhDs; simply, not enough people are adequately qualified.

Table 3. Vacancies and reasons for their existence – breakdown by fields (% of all units)

	Humanities	Social sciences	Medical sciences	Real and technical sciences	Total
Number of vacancies					
Total number	48	93	24	123	288
Percentage of number of PhDs	21.6	34.6	11.5	16.1	19.7
Reasons for vacancies (% of all institutions surveyed)					
Own employee does not qualify.	37	46.2	40	41.9	41.7
Nobody adequately qualified in Estonia	29.6	43.6	80	30.2	36.5
Too low pay	22.2	25.6	20	48.8	33
Peculiarity of research and working conditions rule out hiring a foreigner	29.6	38.5	60	39.5	37.4
Competitions					
Proportion of positions filled by actual competition, %	19.6	14.8	18.1	10.1	14.1
Proportion of PhDs					
Desired percentage of PhDs, %	50.7	63.6	82.8	73.6	66.8
Actual percentage of PhDs, %	29.3	27.1	55.4	54.8	41.6

Note: Units that indicated presence of vacancies included some not indicating the number of vacancies, but indicating at least one since a reason existed for vacancies. We considered such institutions to have vacancies.

Reasons vary for the existence of vacancies. When taking the two reasons "our employees do not qualify" and "no one in Estonia has the appropriate qualifications" together, then in 55% of cases the problem was simply that no one in Estonia is adequately qualified. Other problems mentioned include the low level of remuneration, while another (36%) was that the specificity of research work and working conditions rule out employing foreigners. That finding reflects that in most programmes studies are undertaken in the Estonian language. One important conclusion is that for most institutions 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 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 an option.

Another finding was that only 14% of positions requiring a doctoral degree have been filled as a result of genuine competition; that is, where more than one candidate applied for the position. This could also be interpreted that if a candidate with suitable qualifications exists, then a position will be created. Institutions of applied higher education seem to have relatively more vacancies compared to universities (vacancies constitute 63% of the total number of PhDs employed compared to 16% in universities). The story behind this is most likely that institutions that educate PhDs (large public universities) seem to employ the majority of PhD graduates themselves, and in that way not enough PhDs are available for other institutions. Another issue is the attractiveness of working and salary conditions.

Another factor affecting demand for PhDs is the desired proportion of PhDs among all persons involved in teaching and research. On average, 91% of institutions indicated that their desired proportion of PhDs exceeds the actual proportion; we can assume that in these institutions extra PhDs might be needed. On that basis, it follows that in order to increase the actual proportions to the desired level without dismissing any staff lacking PhD degrees, about 605 (45% of the current number) new PhDs would be needed. Unsurprisingly, the desired proportion of PhDs is much lower in institutions of applied higher education than in universities (respectively 72% and 25%).

We next move on to analyse replacement demand. The most important source of replacement demand is usually retirement. A very high proportion of PhDs – some 45.5% - are at or close to retirement age [17]. In the real and technical sciences this proportion is higher, while in medicine and humanities it is somewhat lower (Table 4). The high proportion of PhDs at retirement age probably reflects various factors: lack of new PhD graduates replacing the ageing workforce, the ability of PhDs to continue working at a relatively old age, and poor retirement pensions [18]. Thus, despite 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.

Table 4. 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
Over retirement age, %	11.7	16.7	3.8	25.0	18.4
up to 5 years to retirement age, %	8.6	11.5	4.8	13.6	11.5
5-10 years to retirement age, %	16.7	18.2	1.9	17.9	15.6
Younger, %	63.0	53.5	89.5	43.5	54.5
Total: over retirement age and up to 5 years to retirement age, %	20.3	28.2	8.6	38.6	29.9

The previous evidence corresponds with the fact that in the past the most important reason for leaving a job has been retirement (as has also been found to be true for other countries, e.g. Cartter, 1971): 48% of PhDs leaving in the last five years have done so due to retirement. Other reasons for leaving, such as going to work abroad or transfer to the private sector, have 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 somewhat surprising, given the intensive emigration of PhDs in Estonia to older EU member States (especially Finland

[17] In the 2000 census, the proportion was 61.3% for all PhDs and 41% for employed PhDs. The share of the population below 45 was 16% and over 55, 62%. The PhD population is thus relatively old in Estonia compared to other countries. Among six OECD countries, the USA had the oldest PhD population with 39% above the age of 55 (Auriol 2007). Thus, expected replacement demand is quite high. The situation is somewhat alleviated by the high activity rate of PhDs over retirement age.

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

and Sweden)[19]. This variation is probably connected to the different age structure in different institutions (younger PhDs are more willing to go abroad); however, our data show no correlation between the number of leavers and the proportion of PhDs more than 10 years from retirement age.

From reasons for resignation we have forecasted replacement demand for PhDs over the next five years in the following way[20]. Numbers leaving due to retirement are calculated as the sum of two categories, staff above retirement age currently employed, and employees with up to five years to retirement age. For those leaving for other reasons, we proceeded from the actual number of leavers in the last five 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 5 reveal that over five years, 40% of PhDs currently employed in academia need replacing. The estimate for the annual average replacement rate over five years (7%) falls rather towards the upper end of the range of values that earlier studies have either usually assumed or derived[21].

Table 5. Replacement, growth, and total demand for PhDs by scientific fields

Indicator	Humanities	Social sciences	Medical sciences	Real and technical sciences	All fields of education, 2007-11
Current number of employees with PhD	222	269	209	765	1465
Total hiring: 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, yearly					
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 a 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 demand in sub categories (here academic fields) due to rounding.

[19] The study by Auriol (2007) on international mobility of PhD holders showed that in a given country the percentage of PhD holders who are citizens of another country 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%).

[20] Because we analyzed demand for the entire academic sector, in constructing the forecast we did not take into account mobility between different higher educational institutions.

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

Moving on to growth demand, our questionnaire approached this issue in two ways. First, we asked respondents to report numbers of additional PhD holders needed at known funding levels, existing research projects, and forecast teaching load; that is, need realisable within current resources. Secondly, we asked respondents to report need for PhDs if financial constraints are discarded; this figure could be determined by and originate from the development plan (strategy) of the institution, for instance. Results were somewhat surprising because the differences between the two were not perhaps as large as we might have expected. Within current actual resources, institutions surveyed preferred to hire 588 additional PhDs over the next five years (40% of current numbers), while without funding constraints the number would be 828 (56% of current numbers). Both numbers are rather high given the current number of PhDs, with annual growth demand respectively 6.3% and 8.6% over the next five years.

Summing up both replacement and growth demand, in academia total demand is in the range of 1100 to 1400 additional employees with a PhD degree, either for replacing leavers or for increasing total PhDs employed. That is remarkably high relative to current PhD numbers (almost 100% of current PhD numbers). We referred earlier to the optimistic expectations of some private institutions whose sustainability is questionable in the context of demographic changes and their limited research activities[22]. Given that more than 90% of demand for PhDs comes from universities and research institutes, these issues do not significantly impact our final conclusions. As to previous estimates for other countries, the share of growth demand in total demand is remarkable high, e.g. in a study on faculty demand in the US during 1987–2012, growth demand accounted for 3-14% of total demand (Shapiro 2001)[23].

5.2. Public sector

We firstly looked into positions where the job description required (or suggested) a PhD degree: five such institutions out of 18 (28%). If actual need were considered instead of the current formal requirement, these institutions would increase to eight. In total we could identify 124 positions needing PhDs. At the time of the survey only 24 of these (19%) were actually filled with people holding a PhD, the rest having a master's degree or even a bachelor's degree, or were unfilled. Given that, approximately 100 PhDs are needed to fill all these positions. So, if unsatisfied demand is satisfied within five years, this would assume that every year about 20 new PhDs are hired. It seems that to a large extent demand will be satisfied by institutions' current employees obtaining a PhD degree parallel to working.

As to future expectations, 10 institutions (52%) found in general that the number of positions requiring PhDs should increase, while five institutions expected need for PhDs to remain at the current level and three could not give an answer. Different reasons prompted respondents' view for change in demand for PhDs in the public sector: changing contents of work, increased knowledge-intensiveness of work, increased share of analytical work, general increase in activity. In summing over the positions, we found that the number of positions

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

[23] In the study by Campbell et al. (1990) on accounting faculty PhDs, the average replacement rate over 25 years was 2.8% and growth demand 2% of the number of faculty holding PhDs.

requiring a PhD should increase by 110 - slightly higher than the number reported above on PhDs currently lacking. We took the larger number of the two as the proxy for future demand.

Due to low PhD numbers in the public sector we did not collect separate information on replacement demand. If replacement demand in the public sector were proxied with replacement demand due to retirements in academia (33% of current PhDs), then total demand would increase to about 135 PhDs. 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 according to the 2000 census) has both supply and demand side reasons. The most common reason indicated by 45% of respondents was "lack of demand in the public sector". This also reflects the attitude still present that PhDs are impractical persons with weak knowledge of "real life". Other demand-side reasons are "mismatch to public sector needs" and "skills are relevant, not a degree". But supply-side reasons are also present: the number of PhDs is relatively small and they found employment in the academic sector (24%), lower salaries in the public sector (28%), work in the public sector is not sufficiently motivating or interesting for PhDs (31%).

Table 6 below summarizes the results. It is difficult to divide demand over various scientific fields. We had information on currently employed PhDs and in what fields institutions would need PhDs (many had no particular preference). Thus, the proportion of growth demand attached to specific academic fields was taken as the average of the two.

Table 6. 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 percentage	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. Private sector

Two scenarios have been proposed for development of the private sector. In the first, R&D expenditures were modelled as a linear growth trend, while the second assumed extensive growth of R&D expenditure. Table 7 presents the parameter estimates of R&D expenditure and PhD equations and Figure 2 depicts forecasts of R&D expenditure. Growth of R&D expenditure is biggest in the secondary sector (31 million EEK yearly, or some 2 million euros). In the tertiary sector, an additional 1 million kroons of R&D expenditure increases the number of PhDs by 0.18; in the secondary sector the number is 0.09. That is logical given that R&D in the secondary sector is supposedly more capital-intensive and R&D in the tertiary sector more human resources-intensive. In the non-profit sector, employment of PhDs is rather high despite relatively low R&D expenditure.

Table 7. The parameter estimates for R&D expenditures and doctorates equartions

	Parameter estimates	
Equation 1 (R&D expenditure)	α_1	β_1
Secondary sector	-26.51	31.06***
Tertiary sector	-114.30	46.90**
Non-profit private sector	-6.51	3.99***
Equation 2 (PhDs)	α_2	β_2
Secondary sector	10.31	0.09**
Tertiary sector	38.43**	0.18***
Non-profit private sector	10.60**	0.50**

Note: *significant at 10%; ** significant at 5%; *** significant at 1%.

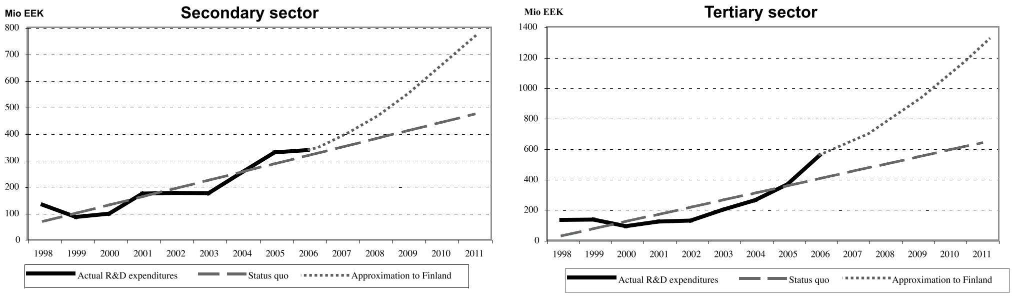

Figure 2 Forecasts for R&D expenditure in the secondary and tertiary sectors: 1st scenario (status quo) and 2nd scenario (approximation to Finland).

The results for the first scenario in Table 8 show that total demand in the business sector during 2007-2011 is about 108 new PhDs or 21-22 a year [24]. The business sector needs most PhDs from real and technical sciences (13-14 PhDs a year) and social sciences (6 new PhDs a year), while need for PhDs in other educational fields is rather limited. Compared to academia, growth demand is thus smaller for humanities and social sciences, and larger for real and technical sciences as well as medical sciences. As expected, private sector need falls significantly below that of academia.

[24] We may have overestimated demand for PhDs in terms of full-time equivalent employees whereas available data do not take into account whether a PhD is employed full- or part-time. For instance, in 2005 2249 R&D employees were in the business sector, but in terms of full-time equivalent employees the number was only 1398 (Statistics Estonia, R&D statistics 2005).

Table 8. Forecast for business sector PhDs 2007-2011 according to the 1st scenario

	Humani-ties	Social sciences	Medical sciences	Real and technical sciences	All fields of education, 2007-11	Total per year
Growth demand	14% (3)	20% (14)	31% (2)	30% (28)	47	9-10
Replacement demand	20.3% (3)	29.4% (16)	29.7% (3)	38.6% (39)	61	12-13
Total demand, 2007-11	6	30	5	67	108	21-22
Total demand, per year	1-2	6	1	13-14		

Source: own calculations.

As a second approach, we considered rapid growth in R&D expenditure. This scenario is linked with the model country approach, by using Finland as the desired target. Finland is one of the most developed countries in the world in terms of knowledge-based society; its R&D expenditures were 3.5 % of GDP in 2005, exceeding not only those of Estonia (0.94% in 2005), but also countries with high R&D expenditure such as Sweden, Japan, and the US. In Finland, too, business sector share in R&D expenditure is remarkably high (69% in 2005 compared to 38% in Estonia). Finland has achieved such a high position only recently: in 1995 its R&D expenditure of 2.3% lagged behind Sweden, the US and Japan, but since 1995 its R&D expenditure has grown rapidly. Moreover, during 1991-2001 the number of R&D employees doubled; growth was relatively faster in universities and the 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). While in 2005 GDP per capita adjusted for purchasing power in Finland was only 1.8 times higher than in Estonia, per capita R&D expenditure adjusted for purchasing power in Finland was 7.5 times higher than in Estonia (Eurostat). Additionally, 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 a poorer research infrastructure.

The bottleneck of the intensive R&D expenditure growth scenario might be private sector capacity to absorb R&D investment, i.e. investment in R&D brings both additional employment of highly qualified professionals and expensive equipment as well as solutions supporting long-term business sector growth. For instance, Spain has shown that innovations were more frequent in the case of PhDs who started to work in enterprises with previous knowledge-absorptive capacity either in terms of a R&D department, previously employed researchers or cooperation with universities or public sector research centres (Cruz-Castro and Sanz-Menendez 2005).

According to the second scenario, real R&D expenditure grows during 2007-2011 at 18% a year[25] and private sector R&D expenditure during 2007-2011 is about 50% higher than in the first scenario (respectively 6.7 and 3.7 billion kroons). Assuming 6% annual real GDP

[25] Because at the time of the study the data on R&D expenditure were published to 2005, numbers for 2006 were forecast with a linear trend and thereafter similarly to the 1st scenario and then assuming a constant 30% growth rate.

growth, by 2011 private sector R&D expenditure will reach 1.1% of GDP (according to the first scenario, the ratio of business R&D expenditure to GDP would remain roughly at the 2006 level, i.e. 0.58%). Thus, Estonia should come much closer to the Finnish level: 2.5% of GDP. As the differences between the two countries' levels of R&D spending are quite big, the short-term goal cannot be about drawing level with Finland but rather intensive rapprochement to Finland. That scenario is in line with the goal set in Estonian R&D strategy to increase business R&D to 1.6% of GDP by 2014 (Teadmistepõhine…2006). Arguably, an 18% annual growth rate of business R&D expenditure is not achievable without growing public support for business R&D (according to Statistics Estonia, in 2005 the state financed only 6.8% of private sector R&D expenditure). The results in Table 9 show that in comparison to the first scenario, demand for PhDs is about 2.5 times higher (52-53 instead of 21-22); for the whole five-year period 261 new PhDs would thus be needed in the private sector.

Table 9. Forecast for business sector PhDs 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	103% (21)	105% (72)	118% (9)	103% (98)	200	40
Replacement demand	20.3% (3)	29.4% (16)	29.7% (3)	38.6% (39)	61	12
Total demand, 2007-11	24	88	12	137	261	52-53
Total demand, per year	4-5	17-18	2-3	27-28		

Source: own calculations.

Concerning earlier estimates, Gabrielsson et al. (2007) forecast growth in the number of full-time R&D equivalent employees in Estonian manufacturing during 2005-2010 based on the assumption that the ratio between R&D employees and companies engaging in R&D would remain constant in the future, and rapid growth in the number of firms engaging in R&D experienced during 2000-2005 (from 141 in 2000 to 357 in 2005) could be extrapolated to the future either with a linear or exponential trend. Depending on the latter assumption, the number of R&D employees was forecast to grow either two or three times, but they also argued these estimates to be rather the minimum given the likely future rise of research. These estimates are thus closer to our second scenario.

6. Final summing up and policy implications

The aim of this paper was to estimate need for new PhDs in the Estonian academic sector, public sector (ministries, state agencies) and business sector over the five-year period 2007–2011. For the first two sectors demand was estimated from surveys among employers, while business sector demand was estimated from a model that assumed PhD demand to be determined by the amount of private sector R&D expenditure. Two scenarios were constructed, one based on continuation of past trends in business R&D spending and the other assuming business R&D to reach 1.1% of GDP by 2011. As with earlier studies, we distinguished between replacement demand (resulting from the need to replace PhDs leaving due to retirement, death, and net movements between different sectors) and growth demand (increase in total PhD numbers employed).

Table 10 below summarizes our results by comparing PhD demand in the academic, public, and private sectors. The results show that demand for new PhD's is rather high in all three sectors. Total demand is even in the most conservative case (assuming current trends in private R&D expenditure and hiring at realistic opportunities in academia) rather high, 80% of current PhD numbers; in the most optimistic case the percentage would increase to 104%. That would increase the percentage of PhDs in total employment from around 0.3% to 0.5%. Shortage of PhDs in the academic labour market is also evidenced by other indicators like the high proportion of vacancies, low proportion of positions filled via actual competition between applicants and the undesirably low proportion of PhDs in total research and teaching staff. Size of demand in relative terms is extremely high in the light of earlier studies. That is largely explained by high replacement demand which can be considered a kind of backlog demand, i.e. the accumulating difference between demand and supply in the past due to insufficient replacement of an ageing workforce. Still, growth demand is even higher and constitutes a higher proportion of total demand than in many earlier studies. While public R&D spending should also increase rapidly in the future in order to reach targets set in R&D strategy that is balanced with the decreasing number of students.

Table 10. Comparison of demand for PhDs

Type of demand	Academic sector		Public sector	Private sector		Total of all sectors
	Hiring with actual potential	Hiring without financial constraints'		1st scenario	2nd scenario	
Current number of PhDs	1465	1465	81	191	192	1737
Incl. Humanities	222	222	13	21	20	256
Social sciences	269	269	21	70	69	360
Medical sciences	209	209	15	6	8	231
Real and technical sciences	765	765	32	93	95	890
Replacement demand, % of current number	40.0%	40.0%	32.8%	31.9%	31.8%	38.8%
Growth demand, % of current number	40.1%	56.5%	135.8%	24.6%	104.3%	42.9%
Total demand, % of current number of PhDs	80.1%	96.5%	168.6%	56.5%	136.1%	81.6%
Incl. Humanities	82.7%	103.9%	156.1%	34.3%	123.3%	82.4%
Social sciences	99.8%	102.8%	165.2%	49.4%	134.4%	93.8%
Medical sciences	46.8%	69.8%	165.5%	60.7%	147.7%	55.0%
Real and technical sciences	77.0%	94.9%	174.4%	68.6%	141.6%	79.6%

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

Briefly, the main reasons for the current shortage of PhDs appear to be past developments such as inadequate supply of new PhDs over several years connected to higher education reforms (Kristapsons et al. 2003), relatively low salaries for researchers compared to much more attractive employment opportunities outside academia, low levels of research funding, a funding system based on past performance not favouring new entrants (Masso and Ukrainski 2008). During 1991-2001 the number of researchers with a PhD decreased by 30% in Estonia (Kristapsons et al. 2003). The reason is also internal brain drain (mobility to commercial and governmental structures) as well as external brain drain (mobility abroad): available data seem to suggest that while leaving the country was important (about 500 people from the Academy of Sciences left during 1989-1993), starting work in public administration and the private sector 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; for this reason, replacement demand plays a relatively smaller role compared to academia. In both sectors, growth demand relative to initial PhD numbers is rather high. In the private sector, demand depends critically on assumed dynamics of R&D expenditure, while in case of continuation of past trends demand is below that of academia, in case of extensive growth of R&D expenditure (to 1.1% of GDP in 2011) demand is relatively highest in the private sector. Total demand would be distributed between the three sectors depending on assumptions and scenarios according to the following proportions: about 80% in academia, 8-10% in the public sector, 8-14% in the private sector. Given that the proportions of current employment are respectively 84%, 5% and 11%, development of PhD studies should consider these changing proportions so that (some) PhD candidates are better prepared for work outside the academic sector. Still the academic sector remains the most important employer.

Total demand divided over five years (280-360 new PhDs a year, annually about 13-15 % of the number of PhDs employed) is relatively close to the figure of 300 which is the expert estimate suggested by the Ministry of Education and Research and is also written in national policy documents, i.e. according to the R&D strategy Knowledge-Based Estonia (2006) the number of PhD defences should reach 300 by 2013 [26]. Thus, a significant unsatisfied demand seems to exist. As to earlier expert estimates, Tiits and Kaarli (2002) argued that about 80 PhDs are needed to ensure continuity of research and education; considering the needs of the public sector and knowledge-intensive enterprises as well, numbers would increase even to 200. By comparison, total PhD defences in Estonian universities in 2006 were 140.

One other conclusion is that private and public sector needs influence demand structure across various scientific disciplines. Compared to academia, public sector demand is relatively higher for social sciences (respectively 20-26% and 32% of total PhD demand) and lower for humanities and medical sciences. Private sector demand is higher for real- and technical sciences; that follows from our modelling assumptions (i.e. that current workforce structure is retained); however, for R&D activities such as product development probably far more individuals are needed from engineering and technical subjects. Thus, the future structure of state-commissioned schooling should focus more on private and public sector needs. Does this estimated demand structure correspond to the current structure for supply of PhDs in Es-

[26] Similar targets have also been set in other countries, for instance in Finland the development plan for education and university research set a target of 1,400 new PhDs during 2000–2004 (PhDs in Finland…2003).

tonia? Table 11 shows that in state-commissioned education the share of real- and technical sciences exceeds the share of graduates; that priority seems to be justified given the structure of estimated PhD demand. In terms of replacement demand, the share of real- and technical sciences is even slightly higher. In general, state-commissioned schooling still corresponds surprisingly well to demand for PhDs.

Table 11. Breakdown of PhD supply and demand across academic fields, 2005

Academic field	PhD students	New PhD candidates	Graduates	State commissioned education	Replacement demand	Total demand
Humanities	17%	18%	18%	13%	10%	15%
Social sciences	27%	25%	18%	20%	20%	24%
Medical sciences	6%	5%	13%	8%	12%	9%
Real and technical sciences	50%	52%	51%	59%	53%	50%
Total	100%	100%	100%	100%	100%	100%

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

In general, in the context of an expected decline in student numbers 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, at least in our survey the majority of respondents (55 %) in academia expected funding to remain at its current level. This may indicate either a low belief among academic staff in government willingness to achieve set targets or that respondents believe funding will be directed to fields other than their own. But high future demand is in our opinion very much related to backlog demand, i.e. unsatisfied demand accumulated over past years since the beginning of the 90s, so that demand exists even in case of declining student numbers and modest growth in R&D expenditure. Growth in research funding is connected not only to PhD demand, but also to the supply of PhDs; according to the survey of PhD students, one-third mentioned difficulties because the supervisor did not have a targeted financed research budget (a major research funding instrument in Estonia), while 71% indicated a shortage of funding for e.g. surveys, experiments (Puura et al. 2004).

Domestic supply of new PhDs may increase if more individuals with master's degrees choose to pursue a PhD due to reduced employment opportunities outside academia following the economic slowdown. Low public funding of higher education and research in Estonia is mostly considered an issue which in our survey respondents sometimes seemed to forget as a reason for shortage of PhDs. [27] If remuneration for the scientific workforce was at an internationally competitive level, international mobility of PhDs could resolve the current shortage. We sincerely hope that finances from European Structural Funds will help to resolve the problem. The Ministry of Education and Research has initiated new programmes to promote

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

PhD mobility, with students able to stay abroad in a partner university for one semester and mobility grants for conferences and shorter visits. One complex of measures introduced is labelled the PhD Schools scheme. This approach is similar to the Centre of Excellence scheme where only a few very good interdisciplinary research centres were awarded EU funding. In 2005-2008 only eight PhD Schools were financed through EU funds in Estonia. PhD School measures cover different activities related to teaching and research, such as funding co-supervisors in partner universities, organising courses and seminars for PhD students, summer schools, mobility grants for shorter visits, or conference organisation. All these measures should improve the quality of PhD studies and increase the number of defences on time. One policy tool introduced in the University of Tartu a few years ago was annual evaluation of PhD students. This kind of tool existed formally in previous years as well, but the university is trying to change it more effectively through certain evaluation procedures and reporting documents.

At the same time it is also important to enhance mobility between different sectors. One policy measure to enhance knowledge exchange between sectors could be grants to businesses in order to employ new graduates of PhD programmes. It is also vital to attract bigger firms to finance PhD students during their studies and later to employ them in order to improve analytical capacity of firms. More generally, a complex solution and policy mix is required to create a system that ensures production and employment of PhDs in numbers that correspond to foreseen growth of R&D expenditure and establishment of a knowledge-based society.

Demand for PhDs in the economy (especially in the public and business sectors outside academia) is still minimised by poor understanding of the meaning of a PhD degree and the role of PhDs in society. Widespread opinion exists 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 or 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 as a top manager in a private company is a matter of choice for each individual and attitudes of society.

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