The Role of PhDs in the Smart Economy

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Forfás

Advisory Council for Science Technology and Innovation
An Comhairle Eolaíochta

Foreword

I very much welcome this Report from the Advisory Science Council (ASC). The ASC is playing a vital role in facilitating Ireland's development into a strong, vibrant knowledge economy. The advice, information and access to stakeholder opinion that the council provides is a very important input to the shaping and refinement of our policies and policy instruments for delivery of the goals as set out in the Strategy for Science, Technology and Innovation 2006-2013 (SSTI).

As the Strategy details, highly educated, professional and effective researchers will be central to the development of the knowledge economy.

More than three years into the lifetime of the SSTI, two Reports on progress made to date have already been published. The results ascertained heretofore have been very positive.

This Report on the Role of PhDs in the Smart Economy is timely. It deals comprehensively and clearly with an issue that is central to the flourishing of the knowledge-based economy on this island. Since 2004, and on foot of an OECD Recommendation, Ireland has increased its output of PhD graduates significantly on the basis that this is key to the realisation of a smart economy.

The report persuasively makes the point that Ireland needs to maintain a competitive output of PhDs in relevant disciplines vis a vis that of other developed countries. Demand for PhD researchers has been growing significantly over the last seven years and it is expected to continue to grow, particularly in sectors where there is already a considerable presence of such graduates.

While it is good to see sustained growth in areas which are already building critical mass in PhD standard human capital it will also be important to see the advance of PhD graduates into other sectors, which may to date have been unrecognised (by both job applicants and employers) as possible areas of employment for a growing cohort of such graduates.

The benefits PhD graduates bring to firms are manifold: new knowledge, working methods, personal networks and ability to solve complex problems.

While it is always difficult to predict precisely enterprise demand for the future, having a considerable output and stock of PhD graduates will help Ireland to attract FDI investment and drive indigenous enterprise development and innovation.

The point is to encourage diverse sectors of industry to avail of a PhD educated component in their workforce and equally to encourage persons qualifying with PhDs to think of career options beyond academia and elsewhere in the public sector.

I would like to thank Professor Anita Maguire who chaired the ASC Task Force on this issue, along with her fellow Task Force members and supporting team, for the extremely useful work that they have carried out in producing this report.

I would also like to thank the Higher Education Institutions, research funders, researchers and those in industry and the public sector who assisted the ASC with their deliberations on and analysis of the topic.

The recommendations contained in the report will be of the utmost importance in setting out a clear path for the role of PhD graduates in the Smart Economy, which can be developed further within the operational structures of the Strategy for Science Technology and Innovation, notably with regard to the evolution, adaptation and overall excellence of structured PhD programmes.

This timely report sheds much light on the role PhD graduates can play as we strive to build Ireland's knowledge economy. We hope that the opportunities that now present themselves can be exploited for the benefit of PhD graduates themselves, their employers and potential employers and for the overall benefit of the Irish economy.

Conor Lenihan TD

Minister for Science, Technology & Innovation

Chairman's Statement

I am very pleased to present the Advisory Science Council's report on the role of PhD's in the smart economy. This report has messages for all of the stakeholders that have a part to play in the strengthening of research and innovation in Ireland.

A flow of knowledge and human capital between enterprise, higher education and the public sector is essential to firmly embed enterprise in the knowledge economy and ensure the recent investment in the research infrastructure is leveraged for economic development in the long term. This report examines the skills that enterprises require from 4th level Ireland, the roles in enterprise that are filled by PhD graduates and also identifies the barriers that reduce the "pull" of graduates to enterprise.

As Ireland increases its R&D intensity in both the HEIs and enterprise the demand for PhD qualified researchers will continue to increase. The availability of these advanced researcher skills is critical to attracting globally mobile investment, stimulating R&D intensity within indigenous enterprise and to sustain and further grow a high-tech sector. Despite the economic downturn the Council is committed to the need for continued investment in PhD education as an underpinning driver of innovation in enterprise.

In the light of constrained resources the Council recommends that Ireland should continue to develop PhD qualifications more closely aligned with broader economic and social needs. The recommendations in this report form a strategy to align skills with enterprise needs and to ensure that skills and knowledge are effectively transferred towards existing and new enterprise development.

I would like to thank the taskforce that produced this report and oversaw the detailed studies that provide the basis for the Council's recommendations. The taskforce was led by Professor Anita Maguire who has given generously of her time to this work and to the Council. I would also like to thank the many researchers, research centre managers, enterprise R&D managers, programme managers and the many other stakeholders who participated in the surveys and workshops underpinning this study. I would also like to acknowledge the research support provided by Forfás.

I believe that the findings and recommendations in this report will have a significant impact on the development of fourth level education in Ireland and its relevance to enterprise and society.

Dr. Tom McCarthy, Chair of the Advisory Council for Science, Technology and Innovation

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Executive Summary

World class research and world class people are at the heart of the national system of innovation. Investments under the Programme of Research in Third Level Institutions and Science Foundation Ireland, in particular, have fundamentally changed the scale and quality of research in Ireland and the infrastructure supporting it. Under the Strategy for Science Technology and Innovation (SSTI) it is planned to build further on the successes to date, through a sustainable system of world class research teams and supporting infrastructure, in addition to transforming the nature of the PhD process through 'structured programmes', while also substantially increasing the output.

The Strategy envisages a significant number of advanced researchers moving into the enterprise sector and for that reason proposes a more structured approach to the professional development of PhD students. The SSTI is consistent with public policies in many countries, which encourage doctoral holders to seek careers in enterprise as a way to foster enterprise-science relationships, upgrade the technological absorptive capacity of firms and achieve a better alignment of skills in the economy.

The Advisory Science Council appointed a task force to examine the enterprise demand for PhD researchers, the roles they fulfil in enterprise and to identify the barriers that reduce the "pull" of graduates to enterprise. This flow of knowledge and human capital is essential to firmly embed enterprise in the knowledge economy, and ensure the recent investment in the research infrastructure is leveraged to lead to economic development in the long term. The study recommendations look to align the skills and knowledge of PhD graduates with enterprise needs. The potential for enhancing the role and delivery of public research organisations, through the employment of PhD qualified graduates, is analogous to those outlined for the enterprise sector.

There is a strong circular and cumulative interaction between knowledge, skills and innovation. An increase in the supply of skills can generate skill-based technical changes, whereby new technologies are invented that promote faster upgrading of the productivity of the skilled workforce. According to the OECD "human capital, especially in science and technology, is of growing importance for innovation and technology-led economic growth. In the new economy where knowledge is the source of wealth creation, human capital becomes as important as financial capital."

The Business Expenditure on Research and Development (BERD) 2001 report showed that BERD as a percentage of GNP for Ireland was 0.95% compared with the OECD average of 1.56%. It was acknowledged in the Building Ireland's Knowledge Economy report (2004) that Ireland's success and growth in the future would depend on the country's ability to transfer the knowledge generated domestically into goods and services for world markets. A strong research base would require highly qualified people and the report predicted that an additional 8000 research personnel would be required by 2010.

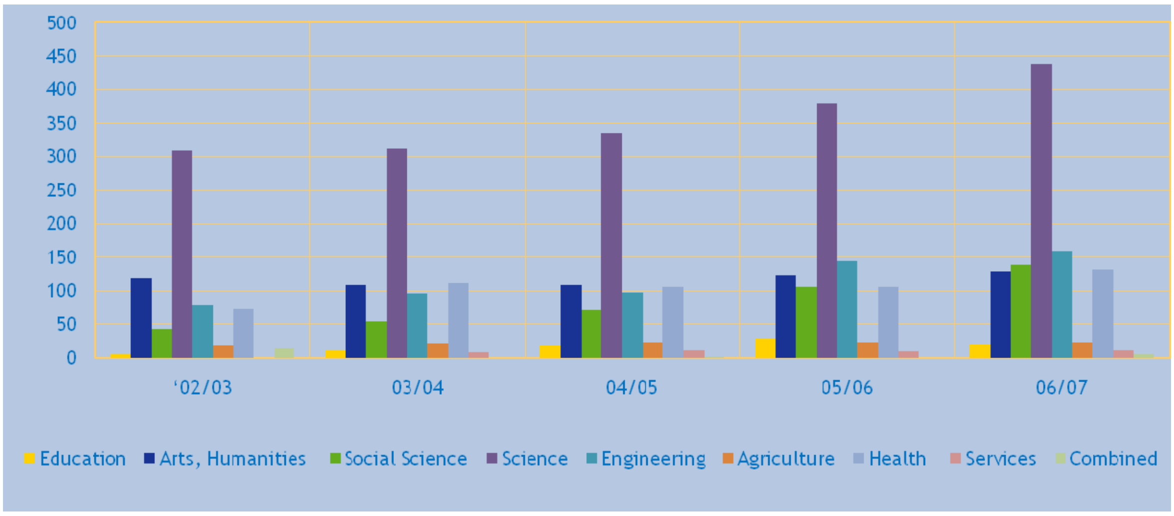
The OECD review of Higher Education, conducted in 2004 recommended that Ireland double its PhD output. At that time the number of PhD graduates per million head of population was at 168, far below high R&D intensity countries such as Finland (356), Sweden (426) and Germany (280). The number of PhD graduates per thousand graduates of tertiary and advanced research programmes at 18 was also far behind Finland (48), Sweden (78) and Germany (105). The OECD argued that the lack of a sufficient supply of doctoral students could seriously hinder Ireland's aim to create a research intensive university system and in turn stimulate much higher levels of industrial R&D.

In 2006 Ireland had increased the number of PhD graduates to 230 per million of population (37% increase) and to 23 (28% increase) per 1000 graduates of tertiary and advanced research programmes. 2006 OECD figures showed that Ireland had one of the fastest annual growth rates of PhD graduates and was slightly ahead of the average throughput of PhDs in Science, Engineering and other fields.

The SSTI in particular looked to build further on the generation of PhD graduate numbers through doubling the annual output on the 2005 base with a target of 1312 PhD graduates in 2013. SSTI did not specify the destination of the PhD graduates or what proportion would be required by the enterprise sector.

PhD output increased from 661 in 2002/2003 to 1055 in 2006/2007 per academic year. Figure 1 shows the number of PhD graduates by discipline from 2002 to 2007.

Figure 1: Annual output of PhD graduates by discipline, 2002 - 2007



Source: HEA website: http://www.hea.ie/en/statistics

Results from the BERD Survey show a growing employment of PhD researchers by enterprise. The total number of researchers employed by enterprise has increased by 1,305 since 2001 to 8,242 in 2007, a 20% increase. In particular the number of PhD researchers has trebled from 420 in 2001 to 1,179 in 2007 and 58% of additional researchers employed since 2001 are PhD qualified. Based on BERD Survey results and enterprise consultations, the number of PhD researchers employed in enterprise is expected to continue to grow, particularly in those sectors where PhDs are already employed. In absolute terms the sectors with the most PhD researchers are Other Services[1], Pharmaceuticals and Chemicals, Electrical and Electronics and Software/Computer Related[2]. The highest proportions of PhD-qualified researchers to other researchers are in the Pharmaceuticals, Chemicals, and Food and Drink sector representing 33% and 20% respectively of all researchers employed in 2007.

As noted in the OECD report, the underlying rationale for doubling the number of PhD researchers is to create capacity within the Higher Education Institutions (HEIs) and enterprise for increased R&D activity. As Ireland increases its R&D intensity in both the HEIs and enterprise the demand for PhD qualified researchers will continue to increase.[3] The availability of these advanced researcher skills is critical to attracting globally mobile R&D investment, stimulating R&D intensity within indigenous enterprise and growing and sustaining a high-tech indigenous sector. Within the current economic environment it is accepted that, as overall expenditure on Science, Technology and Innovation is reduced, the SSTI targets for PhD graduates may not be met; current projections expect the number of graduates to stabilise at circa 960 annually. Enhanced capacity of the enterprise sector to engage in high value-added R&D activity is strongly dependent on the availability of PhD level skills. Therefore, likely future needs should not be based solely on current demand. Despite the economic downturn the Council is committed to the need for continued investment in PhD education as an underpinning driver of innovation in the enterprise sector.

In terms of projecting future skills demands the Expert Group on Future Skills Needs (EGFSN) stated that Ireland's ambition should not be to simply meet projected skills demand based on an extrapolation of current observed trends. If Ireland is to develop competitive advantage in high-level skills, education and training, and transition to a knowledge economy in which skills drive innovation, productivity, and entrepreneurial activity; it requires a skills profile which substantially changes the equilibrium – skewed towards higher levels of skills attainment.

Researchers can enhance the absorptive capacity of firms bringing with them new knowledge, working methods, a personal network and an ability to solve complex problems. These attributes make PhD researchers especially valuable to R&D active firms.

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1 This category accounts for 349 or 30% of all PhD researchers in BERD. 200 PhD researchers in the 'Other Services' sector are employed in the R&D sector. BERD 2007 classified businesses by activity which accounts for the high proportion of R&D companies. 63% of these R&D companies are in the Pharmaceuticals and Chemicals, Electrical/Electronic, Software/ Computer and Instruments sectors

2 This survey was conducted in Q4 2008 and therefore reflects enterprises views in a recessionary environment

3 However, the inevitable dampening effects of the economic downturn on R&D and innovation will lead to a reduction in demand for PHDs in the enterprise sector (at least in the short-run).

R&D active firms employing PhD researchers have rates of patenting 2.5 times greater than similarly active firms which do not employ PhD researchers and have vastly higher collaboration rates with both Higher Education Institutes (HEIs) and other firms. BERD data also shows that while only 29% of R&D active companies employed PhD researchers in 2007, these companies accounted for 70% of BERD.

Given the relatively low numbers of PhD researchers working in enterprise and the specialist nature of the qualification, it is difficult to predict quantitatively enterprise demand in the future. A doctoral qualification is a highly specialised qualification and while PhD-qualified researchers may be recruited on the basis of the topic of their doctoral studies they may equally be recruited on the basis of their broader knowledge and skills. Therefore, it is particularly difficult to forecast the number of PhD graduates demanded by each sector.

In the light of constrained resources, the Council recommends that Ireland should continue to develop PhD qualifications and skills closely aligned with broader economic and social needs. The recommendations in this report forms a strategy for the alignment of skills with enterprise needs and ensuring that the skills and knowledge are effectively transferred towards existing and new enterprise development. Given the concentration of demand for advanced researcher skills in specific sectors, the Council recommends that funding for structured PhD programmes should be broadly aligned with the sectors of the economy, both public and private, where there is evidence of demand or expected demand. The Council understands that the additional criteria in the allocation of competitive funding will have a significant impact on how institutions develop future structured PhD programmes, but believe that it is important to achieving the social and economic impact of the SSTI.

It is clear from the BERD survey that the most important factors when recruiting PhDs from an enterprise perspective are: the underpinning knowledge of the discipline which can be utilised throughout the graduates full career; the relevance of research topic; and the knowledge of research approach, techniques and methods. The Council recommends therefore that structured PhD programmes should embody these elements in the education and training of PhD students. HEIs should also continue to engage with enterprise and should adopt systematic and formal consultation with employers in the development of Structured PhD programmes at discipline level within the institutions.

Given the importance of the underpinning knowledge of the discipline and the relevance of the research topic, a user-friendly, centralised system should be developed to allow employers or potential employers to access information on the number of PhD students in the pipeline and the broad theme of their research. It is also important that the enterprise community are aware of the development in structured PhD training and with what skills and knowledge graduates will emerge.

The IRCSET Enterprise Partnership Scheme links private enterprise and eligible public bodies to co-fund postgraduate scholarships and postdoctoral fellowships. It provides enterprise with access to researchers and the opportunity to build links with relevant academic research groups as well as providing researchers with the opportunity to gain commercial experience. The scheme ensures that PhD students are funded to work in areas of direct relevance to the industrial sector and that on completion the PhD graduates have the skills required by the companies for future employment. The Council strongly endorses the Enterprise Partnership Scheme and recommends that the resources are made available to scale up the programme.

To ensure close alignment between enterprise research needs and PhD graduates the Council recommends the introduction of an Industrial PhD model. The industrial PhD programme, adapted from the Danish model is, as its' name suggests, a programme whereby an employee of enterprise earns their PhD based on research relevant to their company. The objectives of the programme would be to upskill researchers working in R&D active enterprise (industry and services); build know-how, knowledge dissemination and interaction between academic and research institutions and enterprises and finally to ensure commercialisation of new know-how and research, including development of knowledge and technology based enterprises. In Denmark the Industrial PhD programmes accounts for 7% of all PhD graduates and the Council believes that similar targets should be set in Ireland.

While there are some opportunities for PhD researchers within existing R&D-active enterprise, the Council believes that there is potential for PhD graduates to stimulate new enterprise opportunities. A key feature of the Smart Economy approach is to "build the innovation or ideas component of the economy through the utilisation of human capital – the knowledge skills and creativity of people – and its ability and effectiveness in translating ideas into valuable processes, products and services". Therefore the Council recommends that beginning with the PhD education and training period and continuing through to early postdoctoral research stage there should be an integrated programme of support and training specifically targeted at PhD students to enable them to commercialise their research.

Recommendations:

1. Funding for structured PhD programmes should be broadly aligned with the sectors of the economy where there is a strong demand for PhD qualified researchers.

Responsibility: HEA and HEIs

2. Structured PhD programmes should embody the "Inverted T" shaped model for education and training of PhD students.

Responsibility: HEA and HEIs

3. HEIs should continue to engage with enterprise and should adopt systematic and formal consultation with enterprise in the development of Structured PhD programmes at discipline level within the institutions, ideally with the involvement of enterprise boards to oversee structured programmes, where appropriate.

Responsibility: HEA and HEIs

4. A user-friendly, centralised system should be developed to allow employers or potential employers to access information on the number of PhD students in the pipeline and the broad theme of their research.

Responsibility: HEA

5. The Council strongly endorses the Enterprise Partnership Scheme and recommends that resources are made available to scale up the programme.

Responsibility: HEA and HEIs

6. Ireland should develop an Enterprise PhD programme building on the model of the Danish Industrial PhD programme.

Responsibility: HEA with input from enterprise agencies and HEIs

7. Beginning with the PhD education and training period and continuing through to early postdoctoral research stage there should be an integrated programme of support and training specifically targeted at PhD students and early postdoctoral researchers to enable them to commercialise their research.

Responsibility: Technology Transfer Offices and Enterprise Ireland

Introduction

Under the Strategy for Science Technology and Innovation (SSTI), it is planned to further build on the successes to date through building up a sustainable system of world class research teams and supporting infrastructure and by substantially increasing our output of PhDs.

In order to compete internationally Ireland will have to transform new and existing knowledge into innovative, higher value added and productive commercial activities. Human capital will be critical to achieving this goal and the challenge therefore is to ensure that the 4th level contributes effectively to this absorptive capacity.

The Advisory Science Council appointed a task force to examine the skills that enterprise requires from 4th level Ireland, the roles in enterprise that are filled by PhD graduates and to identify the barriers that reduce the "pull" of graduates to enterprise. This flow of knowledge and human capital is essential to firmly embed enterprises in the knowledge economy, and ensure the recent investment in the research infrastructure is leveraged to lead to economic development in the long term. The study recommendations look to align the supply, skills and knowledge of PhD graduates with enterprise needs. The potential for enhancing the role and delivery of public research sector organisations through the employment of PhD qualified graduates is analogous to those outlined for the enterprise sector.

The task force carried out its work through:-

- A quantitative analysis of the employment of PhD graduates, using data from a number of different sources including: BERD Surveys, (2001, 2005 and 2007[4]); CSO Census data (2006); OECD EU data.
- The 2007 BERD data also included questions on the skills and knowledge that employers look for when recruiting PhD researchers and their likelihood of recruiting more PhD researchers.
- Consultation with enterprise including a focus group of companies and representative groups to identify the key issues.
- A review of international literature that analysed the employment of PhD researchers and programmes to support the mobility of PhDs between enterprise and academia.
- A review of the recent Expert Group on Future Skills Needs' sectoral reports to identify demand for researchers and PhD researchers in particular sectors.

4 It is important to note that there was a methodological change in the 2007 BERD survey where NACE codes were classified as an activity and not industrial sector as in previous surveys; this resulted in the emergence of the R&D sector as a significant category.

- A review of national programmes to support the mobility of PhD researchers between HEIs and enterprise.

Chapter 1 - The Role of PhDs in the Smart Economy

1.0 Background

Both economic theory and empirical evidence emphasise the accumulation of R&D[5] and human capital[6] for productivity growth. Investment in education and training improves the productivity of labour and capital - educated workers are more productive, can make better use of physical capital, and are better placed to contribute to innovation or R&D. Investment in innovation or R&D increases the stock of knowledge and the use of that knowledge for new applications. This results in new goods, new processes and new knowledge and, therefore, is a major driver of technical change, productivity growth and overall economic progress. This cycle of knowledge generation, innovation and economic growth is fuelled by a strong engineering and scientific workforce.[7] This is why large increases in education and training have accompanied major advances in technological knowledge in all countries that have achieved significant growth since the mid-1990s, e.g. South Korea, Spain, India, Taiwan, Thailand, and China.[8]

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- Lichtenberg and Siegal, The Impact of R&D Investment on Productivity – New Evidence Using Linked R&D-LDR Data, Economic Inquiry 29 (April), 1991: 203-228.
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- OECD, *R&D and Productivity Growth, Panel data evidence of 16 OECD countries*, 2001
This study of 16 OECD countries, including Ireland, quantifies the long-term effects (1980-98) of various types of R&D on productivity growth. The study found that for any one country, the largest productivity effects are derived from R&D conducted by other countries, followed by the country's public R&D, and then it's business R&D. Specifically,
A 1% increase in foreign R&D generates 0.46 per cent in productivity growth;
A 1% increase in public R&D generates 0.17 per cent in productivity growth; and
A 1% increase in BERD generates 0.13 per cent in productivity growth.
These effects are larger in countries which are intensive in BERD. The long-term impact of R&D may be higher when it is performed by the public sector rather than by the business sector, probably because the former concentrates more on basic research, which is known to generate a higher social return.
- European Competitiveness Report 2001 – Annex IV.2 studies the contribution of R&D to firm performance using a sample of 2167 large publicly funded traded firms in Europe and the US. *"Data shows that firms report R&D are growing faster and have higher productivity. The econometric analysis indicates that the impact is robust, and estimates the rate of return on R&D to be approximately 12%. The data base used provides information on company accounts, sampled from a wide range of manufacturing sectors, for the United States and twelve EU countries covering the period 1989 – 1998.*
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7 -OECD, Mobiising Human Resources for Innovation, 2000
- Pilat, Productivity Growth in the OECD area, Some recent findings, OECD, 2001
- OECD, Workforce Skills and Innovation - An overview of major themes in the literature, 2009
8 South Korea, Spain, Taiwan and India are examples of countries that have invested significantly in

There is a strong circular and cumulative interaction between knowledge, skills and innovation. An increase in the supply of skills can generate skill-based technical changes, i.e. new technologies are invented that enhance the productivity of the skilled workforce.[9] According to the OECD "human capital, especially in science and technology, is of growing importance for innovation and technology-led economic growth. In the new economy where knowledge is the source of wealth creation, human capital becomes as important as financial capital."[10]

1.1 'Two faces of R&D'

In addition to the conventional role of stimulating innovation, engaging in R&D enhances technology transfer by improving the ability of firms to learn about advances in the technological leading edge ('absorptive capacity')[11]. In addition, human capital displays a positive effect on rates of productivity growth by raising the rate at which leading-edge technologies are adopted[12 13 14] Absorptive capacity can be as important as innovation in the make-up of social return from R&D[15].

The role of the two faces of R&D, i.e. (1) absorptive capacity for new knowledge and technology, and (2) innovation, also applies at the individual firm level. The ability of companies to absorb external science and technology developments depends on their internal capabilities, and these capabilities can often be represented by the number and level of scientifically and technologically qualified staff they employ. Personal mobility is one of the most powerful mechanisms through which technology transfer occurs. Therefore, increasing the rate of employment of PhD holders in enterprise will be a critically important factor determining the rate of return from public investment in science and technology.[16]

The objective of this work is to provide recommendations to ensure PhDs and postdoctoral research graduates make an effective contribution to enterprise and optimally contribute to increased innovation in the sector.

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human capital in recent times. See Bergheim (2005) for a discussion in particular, of the success stories of Spain and South Korea. Bergheim, S. (2005) Human Capital is the Key to Growth: Success Stories and Polices for 2020, *Deutsche Bank Research, Current Issues*, August 1, 2005, Frankfurt am Main, Germany.

9 Kim, Young-Hwa (2002), A State of the Art Review on the Impact of Technology on Skill Demand in OECD Countries, Journal of Education and Work, Vol. 15, No 1, pp 89-109.

10 OECD, Mobilising Human Resources for Innovation, 2000

11 - Cohen, W., and Levinthal, D., (1989). 'Innovation and learning: Two faces of R&D', *Economic Journal*, 107, 139-49.

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12 Ibid.

13 Op. cit. Griffith, Redding, Reenen, 2001

14 Kneller and Stevens, Absorptive Capacity and the Technology Frontier, Royal Economic Society Annual Conference 2003, Number 193, 2003

15 Op. cit. Griffith, Redding, Reenen, 2001

16 Callon, M. 'Is Science a Public Good?' Science, Technology and Human Values, Vol 19, pp 395–424

1.2 The Effects of the Downturn on R&D and Innovation

A recent OECD paper[17] outlines the likely effect of the current global economic downturn on R&D and innovation.

Business R&D and new patents increase when GDP increases, and slow down or shrink when GDP slows down or declines. The major reason for the pro-cyclical character of innovation is that investment in innovation is highly sensitive to the financial constraints faced by firms, which is more stringent in downturns. R&D, more than other types of investment, is financed from cash flow, which contracts along with demand, in downturns. In addition, external funding (by banks, markets or investors) of innovation is also sensitive to the business cycle. Innovation is mainly financed by cash flow because external parties, notably banks, are often reluctant to fund innovation that is risky and results in intangible assets which are often not accepted as collateral by banks and financial investors as their value is often uncertain. This reluctance of financial institutions to fund innovation could be even stronger in the current downturn, which originates from over-lending (although not primarily to innovative firms) by the financial sector. The current economic context tends to discourage risk-adverse behaviour by financial institutions and markets, and innovation could suffer as a consequence.

Certain high technology goods are more prone to a reduction in demand than other types of goods and in many cases their purchase can be more easily postponed than, for example, food or pharmaceuticals. Moreover, many companies in high tech industries like IT hardware and software have announced massive lay-offs for the first time in their history.

Some of the benefits of pre-recession expenditures on R&D and innovation might be lost, for example if research projects which were started before the downturn are prematurely interrupted and especially if this occurs at the stage of commercialisation, which is the most expensive phase in the innovation cycle. Moreover, many firms will have a strong incentive to temporarily redirect their innovation capacities towards cost-cutting projects, to the detriment of more ambitious market-expanding endeavours. In this sense, while R&D projects usually take some time to formulate, many are “shovel ready” as the crisis forces companies to abandon or significantly cut-back existing projects. However, the 2009 EU Industrial R&D Investment Scoreboard shows that R&D investment by the top 1,000 EU corporate R&D performers increased by 8.1% in 2008, when Europe was in recession, which suggests that companies see investment in R&D as a good long-term strategy to remain competitive.

The creation of new innovative businesses is likely to suffer given the heightened barriers to entry resulting from the greater difficulty in accessing finance. This is detrimental to economic growth in the long-run as new firms tend to explore the more high-risk innovative avenues and exercise competitive pressures on established firms, hence pushing them to innovate. The more innovation-oriented the new firm the greater the risk it will present for banks and investors who become more risk-adverse in recessions. Fading support by the financial system for firms, but in particular new

17 OECD, A Forward Looking Response to the Crisis; Fostering an Innovation Led, Sustainable Recovery, 2009

entrants, is thus a major concern in the current context. In addition, weaker demand will make life particularly difficult for new firms.

The global downturn is increasing unemployment in most OECD countries and experience from previous recessions, for example in Korea in the late 1990's, shows that many high skilled human resources will also become unemployed. Lay-offs in high tech industries and knowledge intensive services across OECD countries (including Ireland) have been announced almost daily. The OECD warns that "human capital will quickly depreciate if suitable new work opportunities are not created soon."[18]

Another potential threat is that the stock of infrastructure and equipment that has been developed for R&D in Ireland could quickly depreciate or become obsolete if investment is not sustained at a level that keeps this stock in use and up to date in addition to loss of expertise and skilled individuals.

Finally, the OECD point out that as innovation investment declines and certain companies fail, it is possible that knowledge networks are disrupted. Recent years have seen the emergence and increasing importance of innovation networks, which involve partnerships between firms or between firms and universities[19.] These networks are linked to the development of value chains across industries and countries and are aimed at accessing knowledge and at reducing the costs and risks of innovation. In the current crisis, companies may re-internalise some activities as they want to protect themselves against the possible disruption of these chains. On the other hand companies may try to reduce costs by externalising some of their activities further, notably to low-cost countries. As innovative firms increasingly rely on such (often global) networks for their innovative activities, the possible rise in protectionism is particularly threatening as it might increase the costs of innovation.

In order to counter the negative effects of the downturn the OECD[20] recommends sustained investment in R&D, innovation and human capital for an "innovation-led recovery" (please see Annex 1 for further details).

Under the 2007-2013 National Development Plan (NDP), a total of €8.2bn was foreseen for investment over the duration of the NDP to 2013 for science, technology and innovation. As the NDP was predicated on an annual growth rate of 4% expenditure, provision has had to be revised downwards in light of the economic downturn and the consequent deficit in the public finances. The context to the above is that the Strategy for Science Technology and Innovation 2006 - 2013 (SSTI) had been predicated on a ramping up of the investment in R&D over the lifetime of the NDP such as to enhance the bedding down of high added value research and its commercialisation in our economy and thereby add significantly to Irish competitiveness, especially vis à vis those countries with a longer and more established pedigree in R&D.

18 op.cit.OECD, 2009
19 OECD, 2008, Open Innovation in Global Networks
20 Op. cit, OECD, 2009

The reduction in foreseen investment for SSTI programmes over the duration of the NDP will entail a reduction in the ambitious targets of the SSTI, including the target of doubling the output of PhD graduates to 1,312 by 2013. 2009 budget levels dictate that the number of PhD places that can be funded will have peaked in 2008 with PhD output expected to reach 1055 and rather than doubling over the period of the SSTI will fall back to circa 960 annually.

1.3 Benefits to Firms from Employing PhDs

A 2001 review by Salter and Martin[21] presents the training of highly skilled human resources as one of the main contributions of academic research to enterprise. By ensuring a supply of skilled graduates and trained researchers, public research underpins the capabilities of the private sector.

PhDs[22] who embark on a career in enterprise can bring with them, not only the knowledge they acquired directly through their research, but also skills, working methods and a network of relationships, to whom they can turn for support in their professional lives.[23] PhDs' knowledge about recent research and, more importantly, a capacity to solve complex problems, conduct research and develop new ideas makes them especially valuable to innovative firms.[24]

Good scientific training can endow individuals with a tacit ability to acquire and utilise knowledge and apply it in new ways, which may generate a particular attitude of the mind that can be an important contribution to innovative activities.[25]

Highly skilled personnel play an important part in developing firms' absorptive capacity. They can fulfil a "gatekeeping" role[26]– that is, "monitoring technological information external to the firm, identifying which is useful and making it available to other members of the organisation, in a form that they understand"[27]. This is a critical role when the internal knowledge base differs substantially from that of the external actors who supply relevant information, a situation that is

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21 Salter, A.J. and Martin, B.R. (2001) The Economic Benefits of Publicly Funded Basic Research. A Critical Review, Research Policy, 30, 509-532.

22 From Wikipedia: **Doctor of Philosophy**, abbreviated **PhD** (also **Ph.D.**), for the Latin *philosophiæ doctor*, meaning "teacher of philosophy", or alternatively, **DPhil**, for the equivalent *doctor philosophiæ*, is an advanced academic degree awarded by universities. In many English-speaking countries, the PhD is the highest degree one can earn [1] and applies to graduates in a wide array of disciplines in the sciences and humanities. The PhD has become a requirement for a career as a university professor or researcher in most fields.
The detailed requirements for award of a PhD degree vary throughout the world. In some countries (the US, Canada, Denmark, for example), most universities require coursework in addition to research for PhD degrees. In many other countries (especially those with a greater degree of specialization at the undergraduate level, such as the UK) there is generally no such condition. In countries requiring coursework, there is usually a prescribed minimum amount of study — typically two to three years full time, or a set number of credit hours — which must take place before submission of a thesis. This requirement is usually waived for those submitting a portfolio of peer-reviewed published work. The candidate may also be required to successfully complete a certain number of additional, advanced courses relevant to his or her area of specialization.
A candidate must submit a thesis or dissertation consisting of a suitable body of original academic research, which is in principle worthy of publication in a peer-refereed context.[2] In many countries a candidate must defend this work before a panel of expert examiners appointed by the university; in other countries, the dissertation is examined by a panel of expert examiners who stipulate whether the dissertation is in principle passable and the issues that need to be addressed before the dissertation can be passed.

23 Pavitt, K.(1991) What Makes Basic Research Economically Useful?, *Research Policy*, **20**, 109- 119.

24 Op. cit. Salter, A.J. and Martin, B.R. (2001)

25 Ibid.

26 Tushman, M.L. (1977) Special Boundary Roles in the Innovation process, Administrative Science Quarterly, 22, 587-605.

27 Fontes et al, Employment of Young Scientists in the Business Sector, Expecatations and Reality, R&D Management Conference 2004

frequent when a firm embarks on processes of change.[28] In such circumstances, it is also vital that to have "knowledge of knowledge"[29], i.e., to know where useful knowledge is located.

The growing availability of high technology capital has created new products and production systems that will require workers to have greater cognitive skills and to be more adaptable and efficient learners.[30] In addition, the globalisation of research and business activities means the ability to act in an internationally networked environment will assume ever greater importance. This makes PhD skills and attributes increasingly relevant.

The Carnegie Mellon University in Pittsburgh, Pennsylvania identified four categories of transferable skills which PhDs bring to their employment in sectors of the economy outside academia. (Transferable skills can be defined as non-job specific skills which can be used in different occupations.) The headline categories were communication, human relations, problem solving and research skills. The Irish University Association Skills Statement further identified project management, time management and ethics and social understanding as skills/attributes acquired during PhD training.

The potential benefits for enterprise from employing PhDs will vary significantly by firm ownership and sector. Chapter 3 contains case studies to illustrate this point.

In summary, PhDs can bring to firms new knowledge, working methods, a personal network, "knowledge of knowledge", and the ability to perform a number of functions that are crucial to the innovation process primarily solving complex problems, “gatekeeping”, knowledge translation and knowledge absorption. While this study focuses on PhDs in the enterprise sector, PhDs also fulfil other roles in society and a knowledge society requires skills in many different disciplines and sectors.

1.4 PhDs in Firms in Ireland

R&D active companies are more likely to engage in novel, break-through research, as measured by patents (2005 data) (figure 1.1), to collaborate with HEIs and other firms (figure 1.2) (2007 data) and are also more likely to employ PhDs.

28 Cohen, W.M. and Levinthal, D.A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly*, **35**, 128 - 152.
29 Gibbons, M. and Johnston, R. (1974) The Role of Science in Technological Innovation, *Research Policy*, **3**, 220-242.
30 Murnane, R. J., Willet, J.B. and Levy, F. (1995), “The Growing Importance of Cognitive Skills in Wage Determination”, *Review of Economics and Statistics*, 77, 251-26.
Cawley, J., Heckman, J. and Vytlacil, E. (2000), “Understanding the Role of Cognitive Ability in Accounting for the Recent Rise in the Economic Return to Education”, in Arrow, K., Bowles, S. and Durlauf, S. (eds.), *Meritocracy and Economic Inequality*, Princeton University Press, Princeton.

Figure 1.1 Patents applied for and granted classified by firms with PhD-researchers and without PhD researchers, BERD 2005

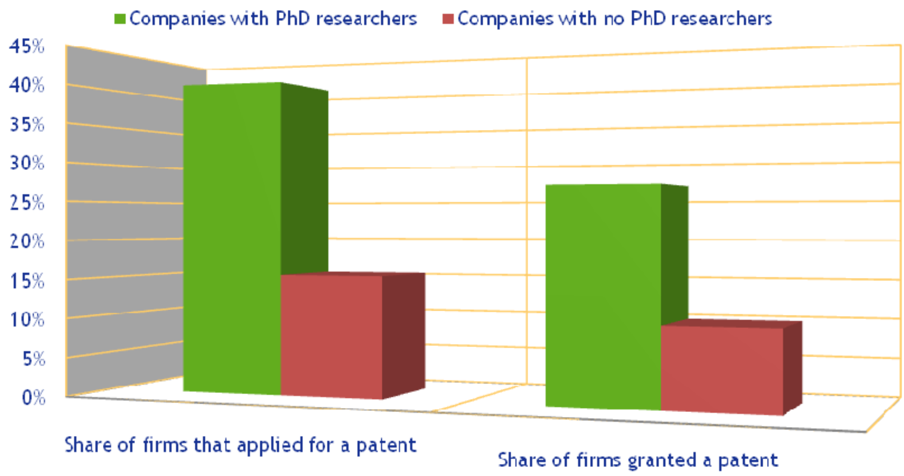
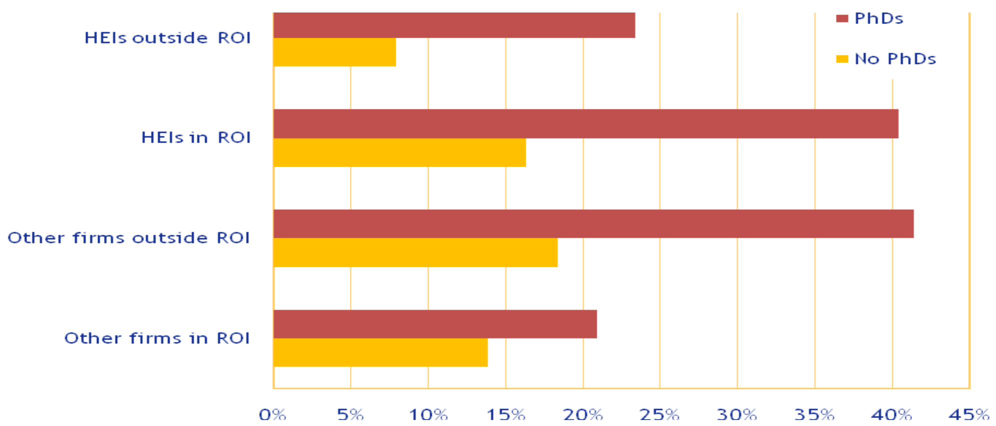


Figure 1.2 Share of firms with joint research projects with parties inside and outside ROI, classified by firms with PhD-researchers and without PhD researchers, BERD 2007



This is consistent with OECD research which shows that the share of S&T workers in firms, irrespective of firm size and sector, has a positive impact on the introduction of new products and processes.[31]

31 OECD, Science, Technology & Industry Outlook, 2008

1.5 Development of 'Fourth Level' in Ireland

Since the late 1990's Irish policymakers have recognised that Ireland's competitive advantages will have to come from higher levels of educational attainment and scientific research and development (R&D). These same advantages will help to drive innovation in indigenous enterprises enabling them to compete in world markets. Given the greater emphasis on knowledge, innovation and R&D in order to compete globally in the 21st century, research skills will be ever more important.

In 1998, the Programme for Research in Third-Level Institutions (PRTLI) was established to strengthen national research capabilities via investment in physical infrastructure and human capital. €865 million has been invested (includes exchequer and private matching funds) through PRTLI programmes to date. The aim of the PRTLI is to establish Ireland internationally as a premier location for carrying out world class research and development. The programme supports research in humanities, science, technology and the social sciences, including business and law.

In 2000 Science Foundation Ireland (SFI) was established to undertake and support strategic research of world class status in key areas of scientific endeavour which would underpin economic development. This research would (1) be of intrinsic excellence acknowledged internationally; (2) be of sufficient scale and critical mass to be effective; and (3) strengthen the scientific foundations underpinning enterprise. To date SFI has invested a total of approximately 1.2 billion in research.

SFI focused its efforts on the niche areas of information and communications technologies (ICT) and of biotechnology, including the underlying scientific disciplines, which were identified as being of strategic relevance to the economy. More recently it has incorporated Sustainable Energy and Energy-Efficient Technologies into its remit.

In 2006, the Government launched its national Strategy for Science, Technology and Innovation 2006 – 2013 (SSTI). Its vision was that "Ireland by 2013 will be internationally renowned for the excellence of its research, and will be to the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture."

The primary rationale for government investment under the SSTI is to develop a competitive knowledge based economy. It aims to drive innovation in enterprise, build human capital and maximise the return on R&D investment for economic and social progress. To create and sustain high-quality employment we need to focus on our rates of innovation activity in enterprise. Increasingly, we need to develop and commercially exploit our own intellectual property as well as new knowledge from around the world.

1.5.1 PhD Researchers

The Business Expenditure on Research and Development (BERD) 2001 report showed that BERD as a percentage of GNP for Ireland was 0.95% compared with the OECD average of 1.56%. It was acknowledged in the Building Ireland's Knowledge Economy report (2004) that Ireland's success and growth in the future would depend on the country's ability to transfer the knowledge generated domestically into goods and services for world markets. A strong research base would require highly qualified people and the report predicted that an additional 8000 research personnel would be required by 2010.

The OECD review of Higher Education, conducted in 2004 recommended that Ireland double its PhD output. At that time the number of PhD graduates per million head of population was at 168 far below high R&D intensity countries such as Finland (356), Sweden (426) and Germany (280). The number of PhD graduates per thousand graduates of tertiary and advanced research programmes at 18 was far behind Finland (48), Sweden (78) and Germany (105). The OECD argued that the lack of a sufficient supply of doctoral students could seriously hinder Ireland's aim to create a research intensive university system and stimulate much higher levels of industrial R&D.

The specific goals of SSTI, 2006 – 2013, are to build a sustainable system of world-class research in terms of people and supporting infrastructure and to double our output of PhD numbers. The two goals are linked as the quality of PhD graduates will in part depend on access to excellent Principal Investigators. The Strategy envisages a significant number of advanced researchers moving into the enterprise sector and for that reason proposes a more structured approach to the professional development of PhD students. Among the priorities of the Strategy are:

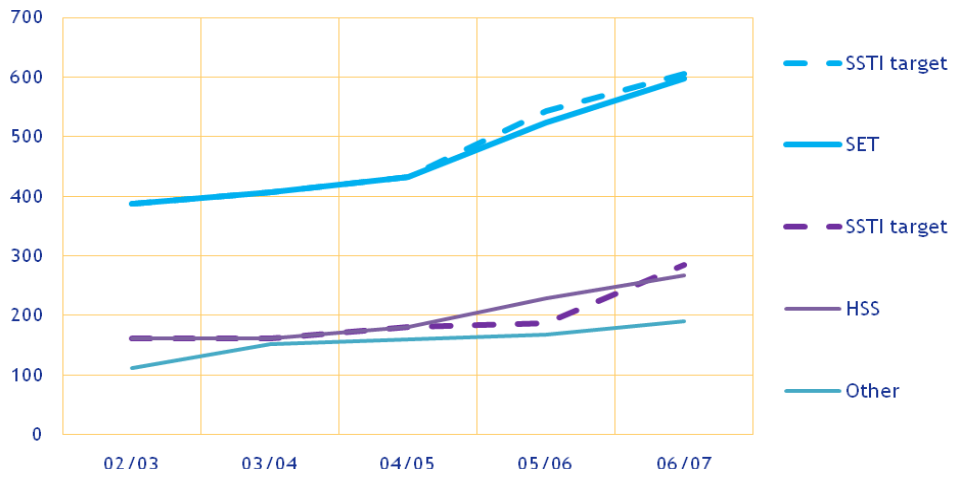
- Growing business expenditure on R&D;
- The movement of researchers from the HE sector to enterprise; and
- The growth of collaboration between companies and research institutions through the development of enterprise led networks and competence centres.

Achievement of these goals will require the employment of more PhD graduates in enterprise. Public policies in many countries have been trying to encourage doctoral holders to seek careers in enterprise as a way to foster enterprise-science relationships, upgrade the technological absorptive capacity of firms and achieve a more efficient allocation of skills in the economy.

1.6 Increasing the No. of PhD's – Strategy for STI 2006 - 2013

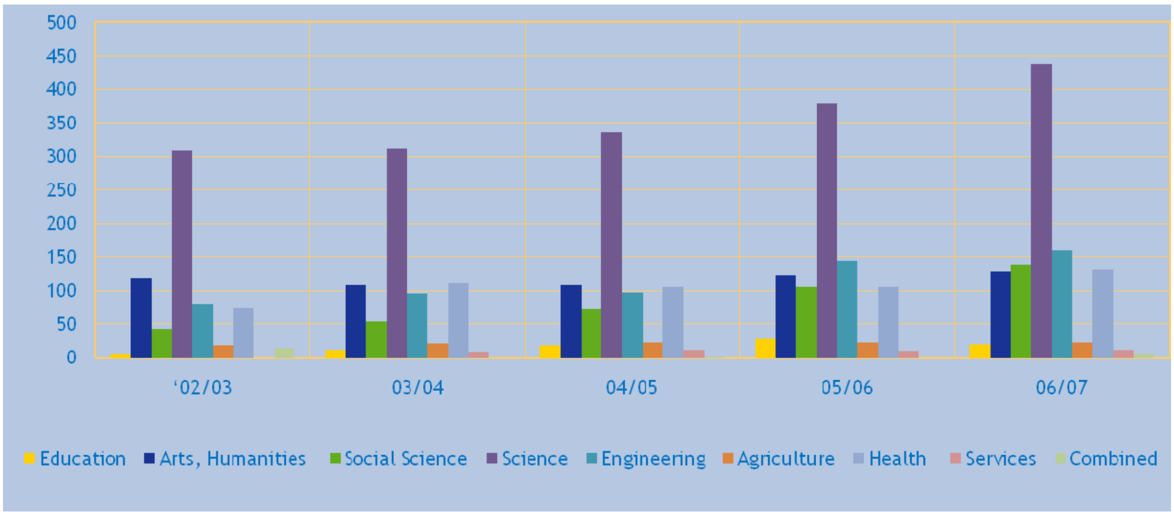
Under SSTI the total number of PhD graduates per year would increase from 730 (543 SET graduates and 187 HSS graduates) in 2005 to 1312 in 2013 (997 SET graduates and 315 HSS graduates) effectively doubling the number of PhD graduates. Below we can see this ramping up taking effect.

Figure 1.3 Number of PhDs graduates by broad discipline, 2003 - 2007



Source: HEA website: http://www.hea.ie/en/statistics

Figure 1.4 Number of PhDs graduates by discipline, 2003 - 2007



Source: HEA website: http://www.hea.ie/en/statistics

The SSTI target to double the output of PhDs by 2013 over the 2005 base has advanced significantly. The most recent data show total outputs rising from 808 in 2005 to 1055 in 2007 ahead of target of 894 in the Strategy. The original goal was to exceed annual output of 1,300 by 2013. A key objective of the strategy is not only to increase the output of PhDs, but to maintain quality and see this knowledge intensive capacity spread through all sectors of the economy.

Recently published BERD data also shows that there has been a significant increase in the number of PhD researchers employed in enterprise, up from 830 in 2005 to 1179 in 2007[32]. This data will be analysed further in Chapter 2.

1.7 Projected demand for PhD researchers

To date there has not been a comprehensive review of enterprise demand for PhD researchers. Given the specialisation of the qualification and the relatively small number of PhD graduates employed as researchers outside the HEIs it is difficult to develop a robust model that would predict demand. However the Expert Group of Future Skills Needs have undertaken a number of studies that have looked at the demand for skills within specific sectors including demand for PhD researchers (some of this work was carried out prior to the economic downturn). Collating the findings from these studies has found that the vast majority of researchers, whether PhD qualified or non-PhD qualified, engaged in the private sector, are employed in the following industries:

- ICT – software and hardware;
- Pharmaceuticals and chemicals;
- Medical devices;
- Financial services;
- Engineering (machinery and equipment); and
- Food and drink.

Of these, ICT, pharmaceuticals & chemicals and medical devices dominate researcher employment. PhD qualified researchers account for a very small share of ICT sector researchers. They account for a higher share in the other main sectors. The sectors with the highest share of PhD qualified researchers are (in descending order):

- Chemicals;
- Pharmaceutical sector;
- Medical devices (instrumentation);
- Engineering; and
- Food and Drink.

These findings are consistent with the findings of the BERD survey. In terms of absolute numbers, the most PhD researchers are in Software, Pharmaceuticals and Electrical and Electronic sectors, accounting for 59% of all PhD researchers in enterprises but the highest ratios of PhD qualified researchers to non-PhD qualified researchers are in the pharmaceutical and chemical sectors.

32 BERD 2007/08: Preliminary Findings: CSO/Forfás, March 2009

The EGFSN studies present a number of observations on the likely demand for PhD researchers in the future:

- Organic growth in activity in an area where significant numbers of researchers are already employed is likely to drive significant demand for researchers, even in the absence of other changes. Only 29% of companies employed PhD researchers in 2007 but these companies account for 70% of the total BERD, an indication that the major R&D performers employ PhD researchers. Therefore, as companies in Ireland become more R&D intensive the demand for PhD researchers should increase, particularly in those sectors where there is a higher ratio of PhD-qualified researchers to non-qualified researchers.
- Some of the demand for PhD researchers will be replacement demand - replacing PhD graduates who move from research work to other roles, or that leave the workforce (e.g. retirement). Most replacement demand will be from industries in which significant numbers of PhD researchers are already employed. (The 2004 EGFSN report assumed that on average the research career of a PhD researcher in enterprise would last 10 years.)
- Where the share of researchers who have PhDs is low, even a modest shift in the PhD/non-PhD mix of new recruits may have a dramatic impact on demand for PhD researchers.

Looking beyond the current economic downturn, there should also be demand for PhDs for research work from other parts of enterprise, for example:

- From expansion of research activity in areas where there is already research activity present at a low level e.g. services sectors;
- Stemming from commercialisation of academic research through new spin-offs and start-ups; - or
- Through inward investment in research operations focused on new business research activity.

However, these activities tend to build up over time. While their long term impact on demand for PhD researchers may be substantial, the short to medium term impact may be limited in the absence of very dramatic successes.

In terms of projecting future skills demands the EGFSN stated that Ireland's ambition should not be to simply meet projected skills demand based on an extrapolation of current observed trends. If Ireland is to develop competitive advantage in high-level skills, education and training, and transition to a knowledge economy in which skills drive innovation, productivity, and entrepreneurial activity, it requires a skills profile which substantially changes the equilibrium – skewed towards higher levels of skills attainment. Good progress has been made in the implementation of the SSTI in a short period of time. Ireland has been moving in the right direction and we should continue to develop PhD qualifications and skills to attract and stimulate enterprise activity including attracting FDI, creating spin-out companies and growing the existing enterprise base, provided that the graduates are of sufficient quality.

The downturn has brought about intense pressure on public budgets, which has in turn led to a reduction in planned public S&T investment. The most recent Government figures show that the revised S&T budget for 2009 is down €117 million on 2008 and €226 million on the NDP budget for this year – a 26% reduction. Funding for existing projects is expected to be maintained going forward but funding for new projects will be limited. Compared to other areas of public expenditure, however, S&T has been protected in relative terms.

A fall in State funding for Science & Technology may inevitably mean that some research capacity and expertise will be lost to Ireland. The highly skilled are also highly mobile internationally and competitor countries are increasing their investment in science and R&D and are targeting areas that can deliver swift returns to accelerate their recovery and drive long-term growth. It is not possible to turn off the funding tap during a downturn and then turn it back on again upon recovery without consequences. For example, Principle Investigator teams are employed on five year contracts and when teams are disbanded they are not easily replaced. We need to continue to develop Centres of Excellence with a critical mass of expertise in order to attract companies. A balance between a 'top down' or directed approach and a 'bottom up' approach to development of such centres is necessary. Enterprise led Research Centres such as Competence Centres can ensure this type of balance.

1.8 Recent Initiatives

1.8.1 Towards a Framework for Researchers Careers

The Advisory Science Council published a report on Researcher Careers in October 2008 which outlined a strategy to drive a step change in the career structure and mobility of researchers. The Council recommended that:

- A national programme be established that provides information and advice on career planning.
- Employers in higher education, the public sector and enterprise should collectively develop a researcher careers competency framework that enables a mutual recognition of experience and skills with the ultimate aim of facilitating mobility.
- Funding should be made available to promote inward and outward mobility of researchers and there should be a structured career path within the HEI's for researchers with rigorous international competition at all levels.
- Competitive research fellowships and senior research fellowships would provide independent funding for researchers who would have already completed the first phase of their career gaining practical experience under the supervision of a Principal Investigator.

1.8.2 Structured Graduate Education Programmes

Structured Graduate Education Programmes are the proposed new approach to PhD education and training undertaken by HEI's individually and the Higher Education Authority. Structured programmes will ensure that PhD students receive the best possible experience and education. Links to enterprise, where appropriate; and the opportunity for skills development and student placements are an integral component.

The traditional model of PhD education could be described as being similar to the “apprenticeship model” - lone or small groups of students situated within a single HEI. The primary focus is their PhD thesis. If they receive any generic/transferable skills training then this is an “extra” and not part of their core training. Typically there is funding for three years while the average PhD completion period is around four years.

The new model proposes a more structured programme with the possibility of more than one supervisor (doctoral committees) and that these may be based in more than one institution. The focus will still be the PhD thesis and contributing a unique body of knowledge. However, the generic and transferable skills will be embedded in their education and training. Funding would be for a maximum of four years. This new approach to PhD education requires changes at a number of levels within the HEI system.

In 2006 a high level Graduate Education Forum was organised by the HEA in partnership with IRCSET and IRCHSS. A number of key guiding principles for Graduate Education in Ireland emerged:

These included:

- Deliver quality-led training of early stage researchers in multi-disciplinary environments;
- Provide structured relevant generic and transferable professional skills training enabling the PhDs produced to develop their careers in diverse sectors of the economy, including intellectual property management and commercialisation skills;
- Facilitate industrial placements and modular, transferable postgraduate courses, both practical and theory based with built-in industrial expertise;
- Provide further training for industrial researchers requiring skills/knowledge upgrading.

Annex 2 describes recent developments in this area.

Annex 1: Stimulus Packages for R&D and Innovation

In order to counter the negative effects of the downturn the OECD[33] recommends sustained investment in R&D, innovation and human capital for an "innovation-led recovery". In a similar vein, the EU has urged its member states to increase planned investments in education and R&D (consistent with national R&D targets) and to consider ways to increase private sector R&D investments, for example, by providing fiscal incentives, grants or subsidies.

Many OECD countries have announced stimulus packages to respond to the economic crisis.[34] In most cases components of these packages are directed towards investment in R&D, infrastructure, education, the greening of the economy, support to innovation and to SMEs. Below are some examples of OECD countries that are increasing their investment in R&D and innovation to hasten their economic recovery and drive long-term growth.

Country	Stimulus - Science, R&D and Innovation	% GDP
Australia	AUD 2.9 Billion	0.25%
Canada	CAD 800 Million	0.05%
Chile	USD 8.8 Million	0.01%
Finland[35]	EUR 25 Million	0.01%
France	EUR 46 Million	0.00%
Germany	EUR 1.4 Billion	0.1%
Korea	USD 36 Billion	-
Norway	NOK 170 Million	0.01%
Sweden	SEK 9 Billion	0.29%
Poland	PLN 16.8 Billion	-
Portugal	EUR 224 Million	0.13%
United States	USD 16 Billion	0.11%

In addition to the stimulus packages many OECD countries are maintaining their targets for R&D and innovation expenditure, e.g. Finland aims to keep its target of extending R&D expenditures to up to 4 % of GDP. In a speech[36] to the members of the National Academy of Sciences (NAS) in April 2009, President Obama pledged to commit 3% of the U.S. gross domestic product to scientific research, development, and education, an amount that exceeds scientific funding during the height of the space race with the former Soviet Union in 1964.

33 Op. cit, OECD, 2009
34 OECD Strategic Response to the Financial and Economic Crisis - Contributions to the global effort, January 2009, http://www.oecd.org/dataoecd/33/57/42061463.pdf.
35 Finland aims keep to its target of extending R&D expenditures to up to 4 % of GDP;
36 http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-at-the-National-Academy-of-Sciences-Annual-Meeting/

The fact that so many of our competitor countries are increasing their R&D and innovation investment will put Ireland at a disadvantage when the economic upturn kicks-in if we don't maintain and build on our investment. Finnish and Korean management of their economic crisis' in the recent past illustrate the value of R&D and innovation policies for the restoration of growth and sustainable development. [37]

37 OECD, A Forward Looking Response to the Crisis; Fostering an Innovation Led, Sustainable Recovery, 2009

Annex 2: Structured graduate education programmes

A recent report[38] (May 2008) of an ERA Expert Group on Researchers and Research Careers noted the findings of a 2007 survey that, in 16 out of 37 countries surveyed, universities have introduced graduate schools that provide structured doctoral education and research training. This includes a move away from the traditional model of the student-supervisor relationship to a more structured research degree programme with independent review at key points and a tailored programme of research and generic/transferable skills development. The report recommended the development of "structured doctoral programmes, moving away from the traditional, highly individualised apprentice model, oriented only to an academic profession, to a new model, oriented to a wider employment market, to give PhD graduates multiple career options in the Knowledge Society."

The IUQB 'Good Practice in the organisation of PhD programmes in Irish Higher Education, National Guidelines 2009[39]' defines a Structured PhD Programme as "A graduate programme of study undertaken by PhD students that maintains a research-based education, but one that is augmented by activities that support the acquisition of a range of relevant specialist and generic skills". The guidelines cover all aspects of the structured PhD programme with sections on the institutional organisation, recruitment admission and general arrangements, induction and communication, supervision and supervisors, the student, the project, professional development, monitoring progress, the dissertation, the examination, the graduation and data records and reporting on PhD programmes.

In essence the structured PhD can be described as a 'PhD in which transferable and disciplinary training is an integral part of the education, and which is characterised by a high quality research experience.' The duration would be four years either as a research Masters transferred to PhD status or as a 4 year PhD with a confirmation step and the milestones would be established by the institution and carefully monitored.

Not all programmes would be identical as the requirements of different disciplines are not identical. However, the basic framework would be consistent. For the HEA review of Structured PhD programmes (Circa 2008) all of the universities and many of the other colleges provided a definition of what they currently consider a structured PhD to be. The table below was provided by the university Deans of Graduate Studies to the HEA in December 2008. There is broad agreement around the core concept, consisting of:

- Taught courses will be integral to the PhD
- Decision point at 12-24 months when the student has the option of either exiting with a Masters degree, or progressing to a PhD degree.
- Years 2-4 of PhD training characterised by a high-quality research experience supplemented by formal training in key technologies, management and communications.

38 http://ec.europa.eu/research/fp6/mariecurie-actions/pdf/careercommunication_en.pdf

39 http://www.iuqb.ie/info/good_practice_guides.aspx?article=a5b735f2-8618-4af8-8713-9bee30a780fd

- Students participate actively in 'Personal/Professional Development Planning' during the four year process.

Some of the institutions elaborated on other recommended aspects – e.g. supervisory teams, four year funding. However, there is a significant level of diversity in how the HEIs describe the concept of a structured PhD. The following table contracts the structured PhD programme.

Table 1: Characteristics of a Structured PhD Programme

Characteristics	Structured PhD Programme
Mode of study	Cohort (specified structure for a group of students) and individual (tailored to needs of individual students) models possible
Named programme	May be a named programme in the University Calendar, particularly in thematic or disciplinary areas; such programmes are approved by the University academic structures and descriptions published and promoted.
Culture/approach	High quality research experience and output with integrated support for professional development.
Taught modules	Integral, and may include both transferable skills development and discipline specific modules
Programme handbook	Yes, calendar entry and normally department/programme handbook
Focus of marketing effort	Yes
Bologna-compliant	Yes and consistent with Salzburg declaration on PhD
Attractive to international applicants	Yes
Admission criteria	Good first degree
Initial registration	4 year PhD programme
Development of research skills	Formalised integrated programme of activities, linked to experience and reflecting disciplinary requirements, compulsory or expected
Development of generic and transferable skills	Formalised integrated programme of activities, linked to experience, compulsory or expected; based around IUA Irish Universities PhD Graduates' Skills statement.
Professional development	Integral, and may include use of professional development plans

Maximum registration period	4 years full-time with some option for continuation and appropriate registration period for part-time students as defined by the HEI.
Duration of funding	4 years
Provision of studentships	Increased number and value of studentships requiring enhanced external funding including support for professional development. High competition for studentships.
Supervision	A principal supervisor, normally with a supporting panel approved by the Institution.
Supervisor Training	Appropriate support and development available for new supervisors; optional support and ongoing development available for experienced supervisors
Monitoring supervision	Supervision conforms to guidelines laid out by the institution and is monitored by Appropriate Committee, and informed by student and Departmental feedback
Progress monitoring	Formal, explicit, criteria-based, institutional
Progression decision	Formal, criteria-based, approved by Appropriate Committee
Transfer/confirmation of PhD registration	Formal, criteria-based, evidence-based, limited role of supervisor(s), may include exam and/or viva
Completion time	Expected time to completion is 4 years.
Completion rates	Improved completion rates.
Complaints procedure	Formal, institutional

Chapter 2 - Analysis of PhD Researchers in the Workplace

2.0 Summary

- An OECD Review of Higher Education, conducted in 2004 recommended that Ireland double its PhD output.

- PhD output increased from 661 in 2002/2003 to 1055 in 2006/2007 and during that time the number of PhD researchers employed in enterprise has almost trebled, from 420 in 2001 to 1,179 in 2007. 58% of the 1,305 additional researchers employed in the business sector between 2001 and 2007 were PhD qualified.

- Enterprise is absorbing the new PhDs and spending more on R&D which has potential economic impact in terms of tax being generated from higher value added goods and services and higher paid employment.

- The ratio of PhD researchers to total researchers is highest in small companies where they account for 20% of all researchers compared with 14% for large firms.

- The highest proportions of PhD-qualified researchers to other researchers are in the Pharmaceuticals & Chemicals, and Food and Drink sector representing 33% and 20% respectively of all researchers employed in 2007.

- In absolute terms, the sectors with most PhD researchers are 'Other Services'40, Pharmaceuticals & Chemicals, Electrical and Electronic, and Software, accounting for 78% of all PhD researchers in enterprises.

- Only 29% of companies employed PhD researchers in 2007 but these companies account for 70% of the total BERD spend, an indication that the major R&D performers employ PhD researchers

40 . The 'Other Services' category accounts for 349 or 30% of all PhD researchers in BERD. 200 PhD researchers in the 'Other Services' sector are employed in the R&D sector. BERD 2007 classified businesses by activity which accounts for the high proportion of R&D companies. 63% of these R&D companies are in the Pharmaceuticals and Chemicals, Electrical/Electronic, Software/ Computer and Instruments sectors.

2.1 PhDs in the Workplace

According to the Central Statistics Office (CSO) Census 2006 there are 14,412 Doctorate holders in Ireland and of these 12,392 are active in the labour force, which is the equivalent of 0.6% of the total labour force.

Of all doctorate holders in the labour force 32% are employed in the manufacturing and services sectors, 46% in the education sector and 16% in health and social work or public administration and defence.

Chart 2.1: Employment of Doctorate Holders by Sector

Source: CSO census data 2006

2.2 PhD-Qualified Researchers in the Workplace

57% of all doctorate holders are employed in research roles across the three sectors: Business, Higher Education and Government. 13% of PhD-qualified researchers in Ireland were employed in the business sector in 2006 but only 7% are employed in research roles within enterprise.[41]

Chart 2.2: Breakdown of Doctorate holders in the Workplace, 2006

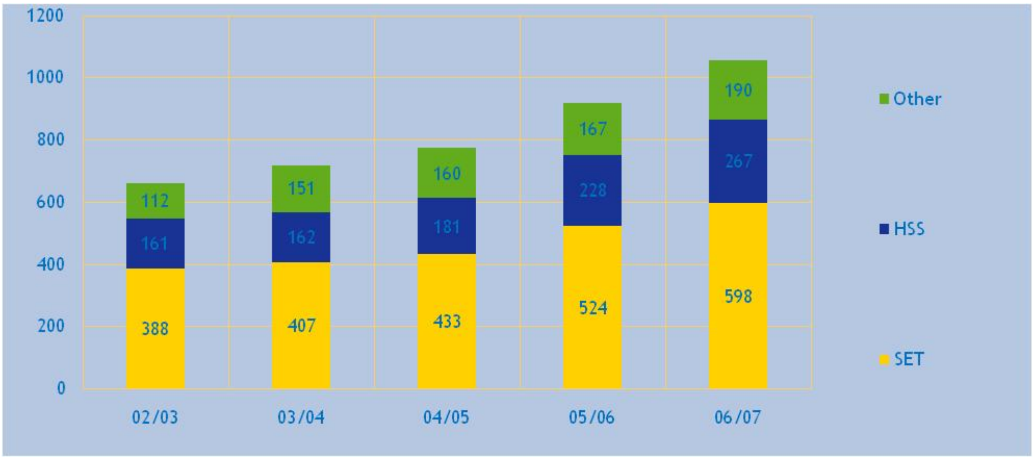
Source: CSO census data and Forfás HERD, BERD and GOVERD surveys

41 Using the 2006 figures from BERD, HERD and GOVERD

2.3 HEA Data on New Graduates

The annual output in 2007 of PhD graduates has increased by 60% since 2002/2003, from 661 to 1,055. In 2006/2007, 57% of all PhD graduates were in a SET discipline and a further 25% in HSS. There has been a 54% increase in PhD graduates in SET disciplines since 2002/2003.

Chart 2.3: Total PhD graduates by discipline, 2003 - 2007



Source: HEA website: http://www.hea.ie/en/statistics

The percentage increase in annual output in 2006/2007 over the 2002/2003 output is 42% in science disciplines, 101% in engineering disciplines and 66% in humanities and social science disciplines.

2.4 International Comparison of Doctorate Holders/ Graduation rates

OECD Review of Higher Education, conducted in 2004 recommended that Ireland double its PhD output. At that time the number of PhD graduates per million head of population was at 168 far below high R&D intensity countries such as Finland (356), Sweden (426) and Germany (280). The number of PhD graduates per thousand graduates of tertiary and advanced research programmes at 18 was far behind Finland (48), Sweden (78) and Germany (105).

The OECD argued that the lack of a sufficient supply of doctoral students could seriously hinder Ireland's aim to create a research intensive university system and stimulate much higher levels of industrial R&D.

In terms of the number of new doctoral graduates relative to the tertiary graduated population, Ireland ranked well below the EU27 average in 2004. Ireland recorded 683 new doctorates awarded in 2004 compared to 48,378 in the US, 23,138 in Germany and 15,257 in the UK. Austria and Germany recorded the highest shares of doctorates awarded among all tertiary degrees awarded at 8.0% and 7.2% respectively.

Table 2.1: Participation of doctorate students, in total and in selected fields of education and as percentage of total tertiary education, in the EU and selected countries, 2004

	In all fields			In science, mathematics and computing			In engineering, manufacturing and construction		
	Total	% female	as % of all tertiary graduation	Total	% female	as % of tertiary education in science	Total	% female	as % of tertiary education in engineering
EU-27	93235	43.4	2.6	26117	39.1	7.4	13000	23.6	2.8
BE	1479	33.9	1.9	658	28.9	9.5	89	20.2	1.2
BG	392	50.8	0.9	77	55.8	3.4	74	39.2	1.0
CZ	1732	35.6	3.2	410	34.9	10.0	468	21.2	5.8
DK	788	35.9	1.7	100	26.0	2.3	376	27.9	8.0
DE	23138	39.0	7.2	6025	29.5	18.7	2107	11.8	3.9
EE	209	62.2	2.0	50	44.0	5.7	16	37.5	1.9
IE	683	45.7	1.2	265	45.3	3.2	108	28.7	1.5
EL	1295	38.1	2.7	711	32.3	8.6	119	21.0	2.4
ES	8168	47.5	2.7	2249	48.9	6.9	603	27.9	1.2
FR	8420	41.7	1.4	4042	38.4	5.3	779	25.9	0.8
IT	6351	50.9	2.0	1931	54	8.1	1177	31.2	2.4
CY	13	61.5	0.4	6	83.3	1.7	..	..	..
LV	84	58.3	0.4	15	63.3	1.2	13	38.5	0.7
LT	301	57.5	0.8	70	61.4	3.8	62	33.9	1.0
LU	..	..	..	..	..	..	..	..	..
HU	893	42.9	1.3	171	32.7	6.4	38	33.3	0.7
MT	5	20.0	0.2	..	..	..	..	..	..
NL	2679	30.4	2.8	499	37.7	7.2	483	23.4	5.8
AT	2443	40.5	8.0	444	35.1	17.2	397	18.6	6.3
PL	5480	48.9	1.1	887	52.9	3.5	908	24.1	2.7
PT	3963	54.7	5.8	1013	51.5	13.8	579	35.6	5.8
RO	2680	49.3	1.8	151	45.7	1.9	690	28.7	2.7
SI	355	40.6	2.4	93	40.9	16.7	86	25.6	3.9
SK	854	45.0	2.4	177	46.3	5.3	155	29.7	3.0
FI	1759	48.7	4.6	306	43.1	9.9	361	26.5	4.4
SE	3834	42.6	7.1	944	39.1	18.3	1096	25.9	9.2
UK	15257	43.1	2.6	4843	37.9	5.6	2218	21.2	4.6
IS	10	50.0	0.4	4	50.0	1.3	..	..	..
NO	756	39.8	2.4	..	..	..	6	50.0	0.2
CH	2952	36.9	4.9	791	32.7	13.3	319	20.4	4.4
TR	2680	38.0	1.0	368	37.8	1.5	418	34.9	0.8
JP	15160	24.9	1.4	2482	19.7	7.9	3355	10.1	1.7
US	48378	47.7	2.0	7211	40.7	3.3	6154	18.5	3.2

EU-27 excluding LU. Exceptions to the reference year: FR, MT and FI 2003 *Source*: Eurostat HRST database
How to read the table: In Belgium, 1.9% of all tertiary graduates achieved a doctorate. Of these 1479 new Belgian doctorate holders 33.9% were female. In details, 658 new doctorates graduated in "Science, mathematics and computing", of which 28.9% were female. These 658 corresponded to 9.5% of the total tertiary graduates in this specific field of education.

For Ireland, 1.2% of all tertiary graduates achieved a doctorate compared with 2.6% as the EU27 average in 2004. Doctoral graduates in science, mathematics and computing represented a 3.2% share of all tertiary graduates in science corresponding to the 7.4% EU27 average. New doctoral graduates in engineering, manufacturing and construction represent a 1.5% share of the total tertiary graduated population in engineering compared to a 2.8% EU 27 average. These figures show the need for Ireland to increase the number of PhD graduates in Ireland in order to catch up with other EU and OECD countries.

Switzerland and Germany are top of the league in terms of the stock of doctorate holders relative to the population and workforce, and new doctoral graduates relative to the total tertiary graduated population.

Ireland has successfully increased the number of PhD graduates. The number of PhD graduates has increased to 1055 in 2007 ahead of the target of 894 contained in the SSTI. The ultimate target is 1312 PhD graduates by 2013.

Based on OECD figures from 2006, Ireland had an annual average growth rate of 17% between 2004 and 2006, which is one of the fastest annual growth rates in PhD graduates in the OECD countries. SSTI did not specify the destination of the PhD graduates or what proportion would be required by the enterprise sector.

Table 2.2 below shows indicators relating to the total stock of doctorate holders in the population as well as indicators on new PhD graduates.

Table 2.2: International Benchmarking of Ireland's Doctorate Holders[42][43]

	Argentina	Australia	Canada	Germany	Portugal	Switzer-land	US	Ireland
Doctorate holders per thousand population	0.2	5.9	6.5	15.4	2.1	23	8.4	5.6
Doctorate holders per thousand workforce	0.5	7.8	8.2	20.1	2.6	27.5	10.7	7.2
Graduation rates at doctoral level	..	1.3	0.8	2	2.5	2.6	1.3	1.2
New doctorates per 100 university graduates	..	2.3	3.9	11.2	7	10.1	2.3	3.2

Source: Auriol, L., Labour Market Characteristics and International Mobility of Doctorate holders: Results for Seven Countries, the OECD, Paris, 2007, Ireland data, Forfás

42 Full explanation of how the indicators in this table were derived in Appendix 1.
43 Table 5 shows the most recent figures available for Switzerland (2003), Germany (2003), US (2003), Canada (2001), Australia (2001), Ireland (2006), Portugal (2004) and Argentina (2005).

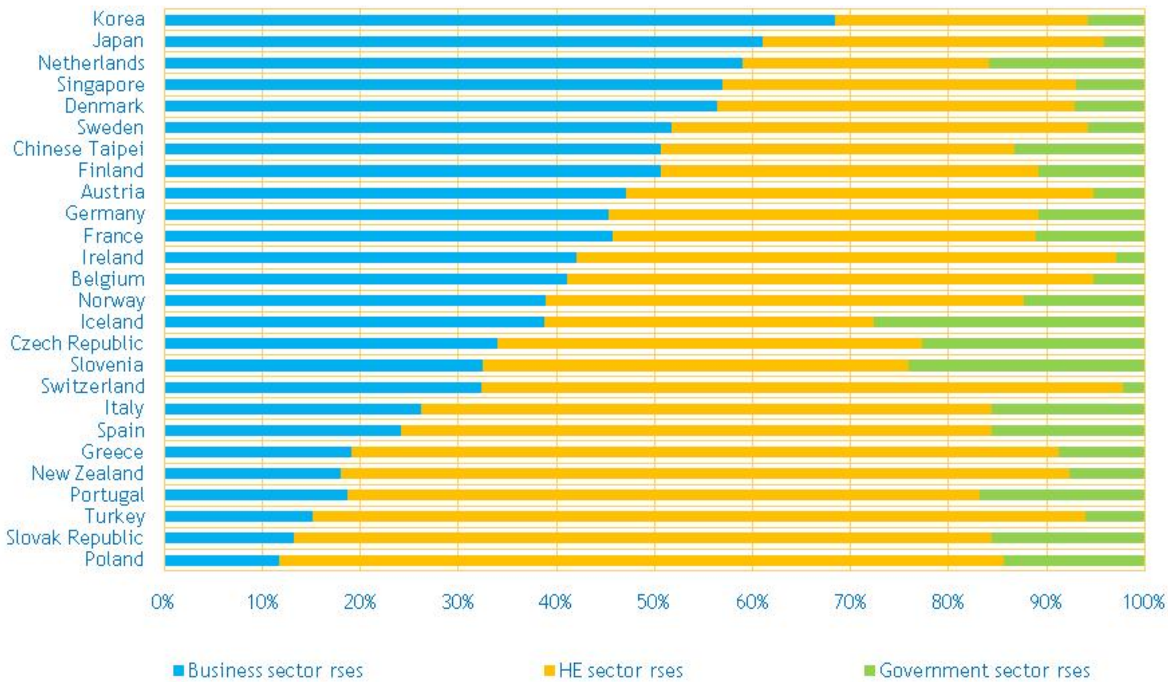
The number of doctorate holders per thousand in the workforce in Germany is almost twice that in the United States. Switzerland and Germany have a long tradition of doctoral education. Ireland's performance ranks closely with Australia and Canada on the above indicators.

2.4.1 Total Researchers by Sector

Chart 2.4 shows international comparisons of the share of researchers employed in the business, higher education and Government sector in 2005. Korea and Japan have the highest shares of researchers employed in the business sector, 68% and 62% respectively. Researchers (PhD and other) in Ireland are more evenly distributed across the business sector (42%) and higher education sectors (55%).

Separating out PhD researchers only, the sectoral breakdown is quite different, with 82% of PhD researchers employed in the Higher Education sector and only 12% employed in the business sector in Ireland in 2006.

Chart 2.4: Share of total researchers (PhD and non-PhD) by sector, 2005 or nearest year



2.5 Business Expenditure on Research and Development

2.5.1 Expenditure

Business expenditure on R&D has been estimated to have increased by 87% from €900 million in 2001 to €1,687 million in 2008.

In 2007, Gross Expenditure on Research and Development (GERD) is €2,443 million. This currently represents about 1.45% of GNP and is below the EU average of 1.77%. Of this 66% or roughly two-thirds is spent by the Business Sector, 27% by the higher education (HE) sector and 7% by Government. There have been significant increases across all three sectors since 2001.

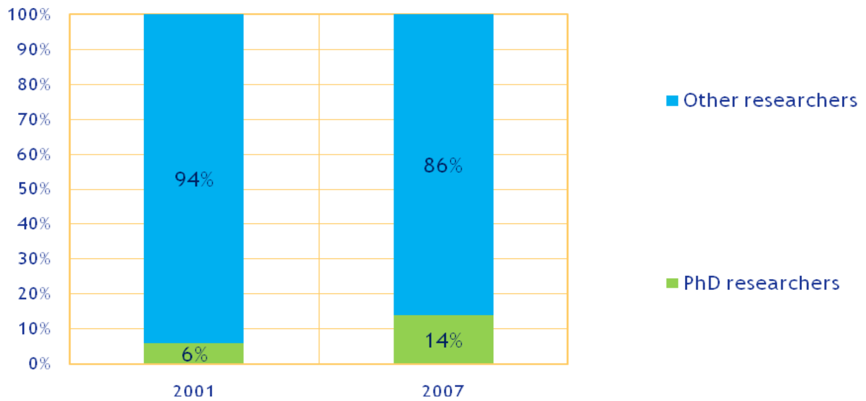
2.5.2 Research Personnel

The business sector accounted for 66% of Gross Expenditure on R&D (GERD) and 44% of total research personnel in 2007. Business expenditure between 2001 and 2007 increased by 78%, expenditure on labour costs increased by 64% and there has been a corresponding 13% increase in R&D personnel suggesting that increases in labour costs have driven this increase in expenditure rather than increases in the number of personnel. This increase in labour costs may be a result of the increase in the number of PhD researchers which is referred to below.

2.5.3 PhD-Qualified Researchers

The number of PhD researchers in enterprise has almost trebled in the six year period 2001-2007, from 420 in 2001 to 1,179 in 2007. 58% of the 1,305 additional researchers employed in the business sector between 2001 and 2007 were PhD qualified.

Chart 2.5: BERD researchers, PhD and non-PhD, 2001 and 2007



In 2006, 82% of all PhD qualified researchers were employed in the higher education sector, 12% in the business sector and 6% in the public sector.

There were 8,242 (PhD and non-PhD) researchers in the business sector in 2007, representing a 19% increase since 2001. In 2007, 14% of business sector researchers were PhD qualified compared to 6% in 2001 as shown in chart 2.5. Non-PhD researchers have increased by 8% over the same period. While 86% of the total researchers in the business sector are not PhD qualified in 2007, 58% of the additional 1305 researchers in the sector since 2001 are PhD qualified indicating a strong shift in preference for fourth level qualifications for research roles.

2.5.4 Small Firms vs. Large Firms

The ratio of PhD researchers to total researchers is highest in small sized firms where they account for 20% of all researchers compared with 14% for large sized firms.

In 2007, medium/large firms accounted for 83% of BERD and small firms accounted for 17%. There were 8,242 researchers employed in the business sector in 2007 and 1,179 (14%) were PhD qualified. Small firms (0-49 employees) accounted for 27% and large firms (250+ employees) accounted for 44% of all researchers employed in the enterprise sector. However, small firms employed 37% and large firms employed 42% of the cohort of PhD qualified researchers in the enterprise sector. Therefore, the ratio of PhD researchers to total researchers is highest in small companies where they account for 20% of all researchers compared with 14% for large firms. This may be accounted for by the number of campus spin-off companies and high-technology start-up companies within Enterprise Ireland's client base.

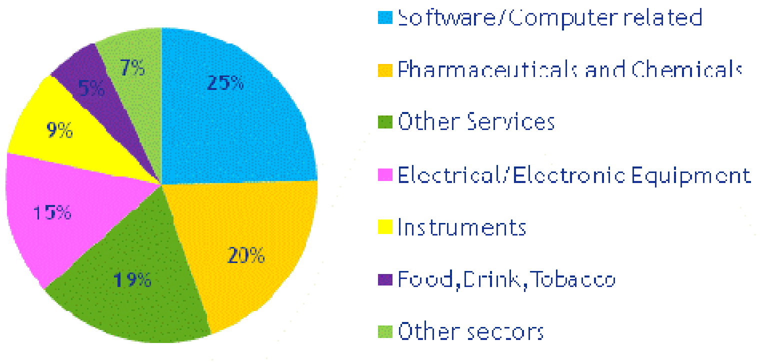
2.5.5 Expenditure - Sectoral Analysis

The main R&D performing sectors in 2007 classified by R&D expenditure were the software and computing, pharmaceuticals and chemicals, other services (including R&D companies) and electrical and electronic equipment, making up 78% of total BERD in 2007.

The sectors with the highest BERD spend by firm size are:

- Small firms: 82% of BERD spend in is in 'other services' sector and software;
- Medium firms: 31% of BERD spend is in software;
- Large firms: 22% of BERD spend is in electrical/electronics.

Chart 2.6: Breakdown of BERD by Enterprise Sector, 2007



2.5.6 Researchers

The BERD 2007 survey shows there are four dominant research sectors both in terms of research spend and number of researchers employed. Software and Computer Related activities, Other Services, Electrical and Electronic Equipment and Pharmaceuticals and Chemicals together account for 79% of BERD and 80% of all researchers employed in the business sector. The next sector with the highest employment of researchers is Instruments (7%) followed by the Food, Drink and Tobacco sector (6% of the total).

2.5.7 PhD-Qualified Researchers

Only 29% of companies employed PhD researchers in 2007 but these companies account for 70% of the total BERD spend, an indication that the major R&D performers employ PhD researchers.

32% of companies have no researchers employed; presumably these companies undertake development work only. This cohort of companies accounted for €165m or 10% of BERD in 2007. A further 458 companies, or 38% of the population, employed non-PhD researchers only and spent a €317m on R&D (20% of total BERD).

The highest proportions of PhD-qualified researchers to other researchers are in the Pharmaceuticals and Chemicals sector, and Food and Drink sector representing 33% and 20% of all researchers employed respectively in 2007.

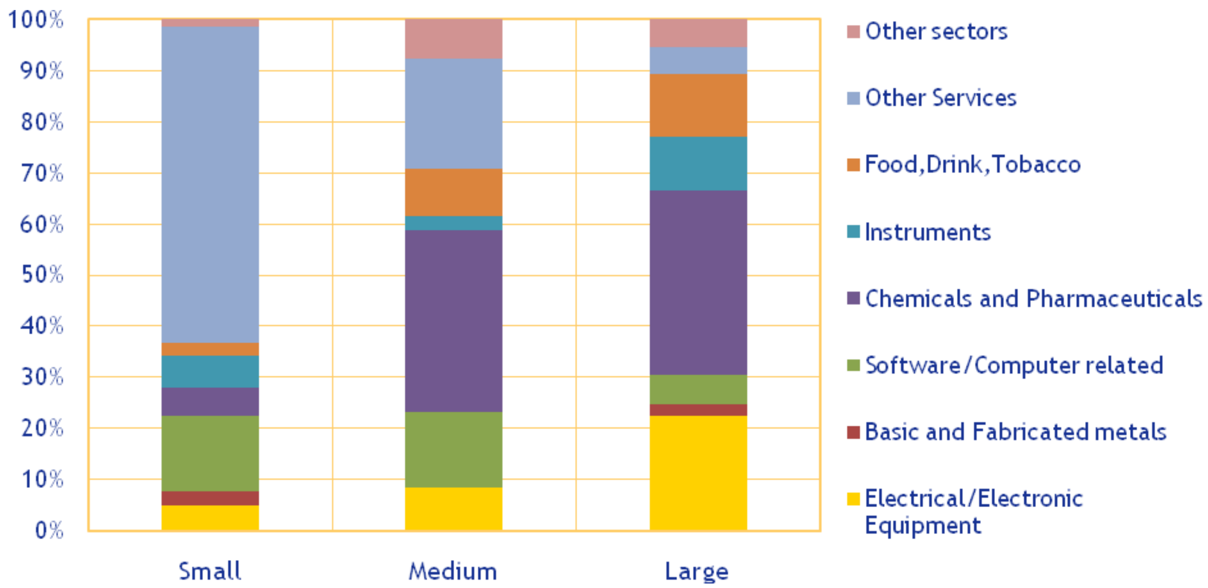
In absolute terms, the sectors with most PhD researchers are 'Other Services', followed by Pharmaceuticals & Chemicals, Electrical and Electronic, and Software, accounting for 78% of all PhD researchers in enterprises. The 'Other Services' category includes companies who conduct R&D on behalf of others (R&D sector) and accounts for 349 or 30% of all PhD researchers in BERD. 200 PhD researchers in the 'Other Services' sector are employed in the 'R&D sector'. A change in the survey methodology has resulted in a very high increase in the number of PhD researchers in the 'R&D sector'. While the 2007 and previous BERD surveys used Nace codes to classify companies, in 2007 it was categorised as an activity and previously it had been categorised by industrial sector. This accounts for the high proportion of R&D services companies - 63% of companies in the 'R&D sector' are companies which previously would have been included in the Pharmaceuticals and Chemicals, Electrical/Electronic, Software/ Computer and Instruments sectors.

Table 2.3: PhD and non-PhD researchers by industrial sector, 2007

Industrial sector	PhD	Non-PhD	Total	% PhD researchers
Pharmaceuticals & Chemicals	290	578	868	33%
Food, Drink, Tobacco	94	381	475	20%
Other Services	349	1454	1803	19%
Instruments	86	468	554	16%
Electrical/Electronic Equipment	153	901	1054	15%
Other	75	544	619	12%
Software/Computer related	131	2738	2869	5%
Total	1179	7063	8242	14%

The proportion of PhD qualified researchers to total researchers found in the Pharma & Chemicals (33%) and Food & Drink sectors (20%) are significantly greater than those found in software and computer related activities (5%), and 'other sectors' (12%) and electrical/electronic equipment (15%). Conversely, 55% of the 8242 researchers in the business sector are employed in software, electrical and electronic equipment and 'other sectors'.

Chart 2.7: Sectoral breakdown of firms with PhD researchers, by size of firm, 2007



There are almost as many PhDs employed in small firms (37%) of 1-49 employees as in large firms (42%) with 250+ employees.

In small firms 62% of all PhDs are employed in the other services sector, followed by 15% in the software sector. In medium sized firms, the dominant sectors are chemicals and pharmaceuticals (35%), other services (22%) and software (15%). In large firms, chemicals and pharmaceuticals (36%), electrical/ electronic (22%) followed by food, drink and tobacco with a 12% share.

Annex 3: Researchers in the Government sector Research performing organisations

70% of all researchers in the Government sector have a PhD qualification. Almost half of all PhD researchers in this sector are employed in Teagasc and are mainly involved in agricultural research.

Table A1: Share of PhD researchers employed in Public Sector Research Organisations, 2007

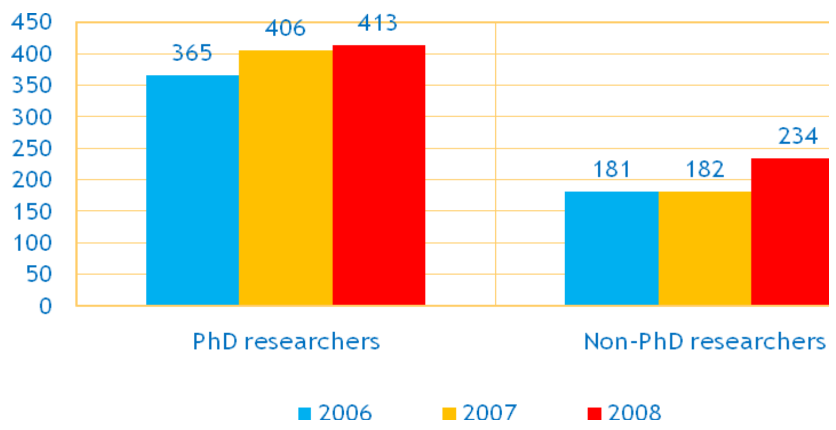
	PhD researchers	Total researchers	% PhD of Total
Teagasc	190	201	95%
Dublin Institute for Advanced Studies	37	55	67%
Economic and Social Research Institute	35	48	73%
Marine Institute	26	51	51%
Food Safety Authority of Ireland	23	23	100%
Department of Agriculture and Food	19	33	58%
Department of Communications, Energy & Natural Resources	15	41	37%
Central & Regional Fisheries Board	11	17	65%
Bord Iascaigh Mhara	8	21	38%
Met Éireann	7	10	70%
Central Bank	7	9	72%
Health Research Board	6	29	21%
Radiological Protection Institute of Ireland	4	10	40%
Department of Arts, Sport and Tourism	2	4	50%
Forfás	2	2	100%
National Roads Authority	2	6	33%
Department of Education and Science	1	1	100%
Department of Social & Family Affairs	0	4	0%
	395	565	70%

Forfás Science budget Survey 07/08

Total Number of Researchers in the Government Sector

There has been a steady increase in the number of PhD researchers employed between 2006 and 2008, increasing by 14% over the period.

Figure A1: Total number of Researchers in the Government sector, 2006- 2008



Annex 4: Explanation of how these indicators were derived

Table A2: International Benchmarking of Ireland's Doctorate Holders

	Argentina	Australia	Canada	Germany	Portugal	Switzerland	US	Ireland
Doctorate holders per thousand population	0.2	5.9	6.5	15.4	2.1	23	8.4	5.6
Doctorate holders per thousand workforce	0.5	7.8	8.2	20.1	2.6	27.5	10.7	7.2
Graduation rates at doctoral level		1.3	0.8	2	2.5	2.6	1.3	1.2
New doctorates per 100 university graduates		2.3	3.9	11.2	7	10.1	2.3	3.2

Source: Laudeline Auriol, OECD

1. Number of doctorate holders per thousand population:

The census figures show a total number of doctorate holders in 2006 to be 14,419. The number of doctorate holders aged 25-64 was 12,798. The population from the Census in 2006 was 4,239,848. However the population aged 25-64 was 2,274,741. This yields the number of doctorate holders per thousand population (using figures for 25-64 cohort only) as 5.6.

2. Number of doctorate holders per thousand labour force:

The census ascertained the number of doctorate holders in the workforce to be 12,392. The number of doctorate holders age 25-64 in the workforce is 12,798. The CSO Census 2006 reported the total labour force to be 2,109,498. Of this, the number aged 25-64 was 1,778,465. This yields the number of doctorate holders in the labour force per thousand labour force (using 25-64 cohort figures) as 7.2.

3. Graduation rates at doctoral level

That is the number of persons receiving a doctoral degree as percentage of the population at the typical age of graduation.

There were 919 PhD graduates across all subjects in 2005/2006 according to the HEA.

The typical age for PhD graduation is taken to be in the age range 25 to 29. The Census 2006 records 373,078 persons in the age range 25 to 29 out of a total population of 4,239,848. If we take as an estimate of the population at any particular age within this age bracket as 20% of the total, this means an estimated 74,616 persons were aged 26 for example. This means an estimated 2% percent of the total population was at the typical age for PhD graduation.

Thus 919 PhD graduates at age 26 out of a total population of 74,616 aged 26 yields 1% as the number of persons receiving a doctoral degree as a percentage of the population at the typical age of graduation. (c.f. OECD avg 1.3; EU19 avg 1.4)

4. New doctorates per 100 university graduates:

There were 919 PhD graduates across all subjects in 2005/2006 according to the HEA.

The number of graduates at Masters level was 6447, at undergraduate Honours Degree level was 16924 (FT and PT) and at Postgrad Diploma was 4,735.

These figures yield a figure of 3.2 new doctorates per 100 university graduates in 2005/2006. The total number of doctorate holders, determined in the 2006 Census, allows international comparisons to be made between the stock of doctorate holders in Ireland and the stocks in other advanced economies. Table A2 shows the number of doctorate holders per thousand in the workforce for Ireland compared with seven other countries.

Chapter 3 - Attitude of Employers to PhD skills and qualifications

3.0 Summary

- Demand for PhD researchers is higher in companies that currently employ PhD researchers. 30% of all R&D performing companies intend increasing the number of PhD researchers by 2013 compared with 61% of companies that currently employ PhD researchers;

- Of all R&D performing companies, the pharmaceuticals, chemicals and instruments sectors have expressed the strongest demand for PhD researchers and the software and computer sector and electrical and electronics sectors have the lowest;

- There is a clear preference for firms to employ experienced PhD researchers rather than newly qualified PhD researchers;

- An underpinning knowledge of the discipline was ranked a highly important factor when recruiting PhD researchers by 68% of firms with PhD researchers employed, compared with 41% of firms without PhD researchers currently employed;

- Knowledge of the research approach and techniques and methods associated with the field of research was ranked as highly important when recruiting PhD researchers by 96% of chemicals companies and 91% of pharmaceuticals companies that currently employ PhD researchers;

- The relevance of the research topic was a highly important factor to consider for employing PhD researchers by 71% of firms in the software and computer sector with PhD researchers employed;

- The availability of candidates with relevant knowledge of the research topic was cited as a highly important hampering factor by 43% of companies that currently employ PhD researchers;

- 38% of companies not currently employing PhD researchers responded that the main factor hampering the employment of PhD researchers was that the company R&D activity did not require PhD skills or knowledge.

3.1 Analysis of the ASC questions included in the BERD 2007 survey

The Council added question 7[44] on recruitment of PhD researchers to the Forfás/CSO BERD 2007 survey. Firms were asked: -

- how likely they were to increase the number of PhD researchers employed in their firm by 2013;
- how likely they were to increase the number of newly-qualified PhD researchers by 2013;
- to rank factors to consider when recruiting PhD qualified researchers in order of importance;
- to rank impacts on the firm arising from the employment of PhD researchers in order of importance; and
- to rank factors that hamper the employment of more PhD researchers in order of importance.

The question on impacts on the company of employing PhD researchers was interpreted in different ways and a reliable analysis of this question could not be carried out.

The total population of R&D performing companies in the BERD 2007 survey was 1,200, and of these 354 companies (30%) had PhD qualified researchers employed. A survey of the major public research organisations in Ireland was also carried out as part of this study to determine demand for PhD researchers in this sector, the results of which are consistent with the results from enterprise.

3.1.1 Likelihood of increasing PhD researchers in enterprise by 2013

Figure 3.1 below shows that only 30% of all R&D performing companies intend to recruit more PhD researchers in the period 2008 to 2013. Almost half of these companies indicated that they will not increase the number of PhD researchers.

Figure 3.1: Likelihood of increasing PhD numbers by 2013, all firms

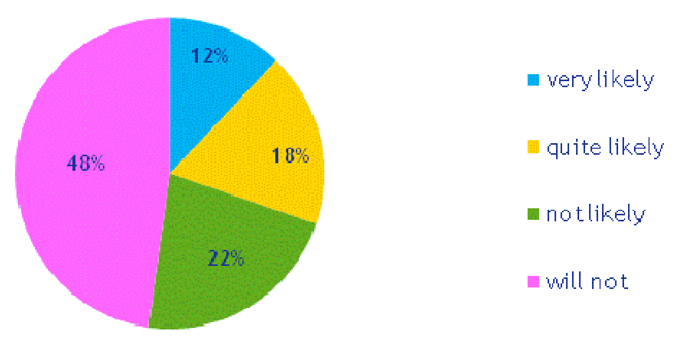


Figure 3.2 below shows the response of companies that currently employ PhD researchers to the same question. In contrast, 61% of these companies indicated that they are likely to increase the

44 BERD 2007 questionnaire in Appendix

number of PhD researchers employed by 2013 with only 20% indicating that they would not increase the number of PhD researchers employed. Only 18% of firms that don't currently employ PhD researchers are likely to or intend to employ PhDs in the future.

Figure 3.2: Likelihood of increasing PhD researchers by 2013, by firms with PhD researchers currently employed and firms without

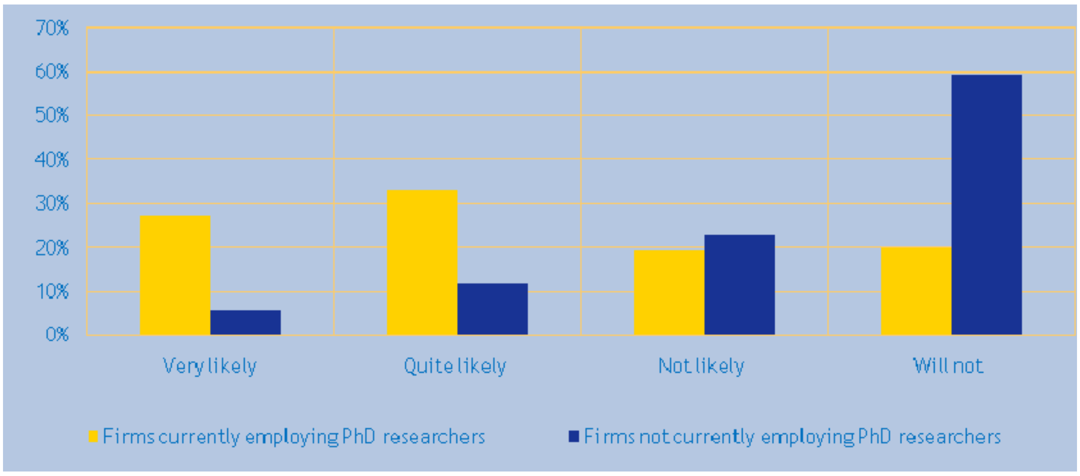


Figure 3.3 shows the likelihood of all firms to increase the number of PhD researchers over the period 2008 to 2013 by industrial sector. There is a great deal of variation by industrial sector. In the pharmaceutical sector 70% of firms intend to increase the number of PhD researchers by 2013, followed by 45% of firms in the chemicals sector, and 41% of firms in the instruments sector. Conversely, 76% of firms in the software/computer are unlikely to or will not increase the number of PhD researchers by 2013, followed by 75% of firms in the electrical in and electronics sector and 74% of firms in the food, drink and tobacco sector. This illustrates that not all high tech sectors require PhD skills and qualifications and that demand for these skills is strongly concentrated in the pharmaceuticals (70%), chemicals (45%) and instruments sectors (41%).

Figure 3.3: Likelihood of increasing the number of PhD researchers, all firms

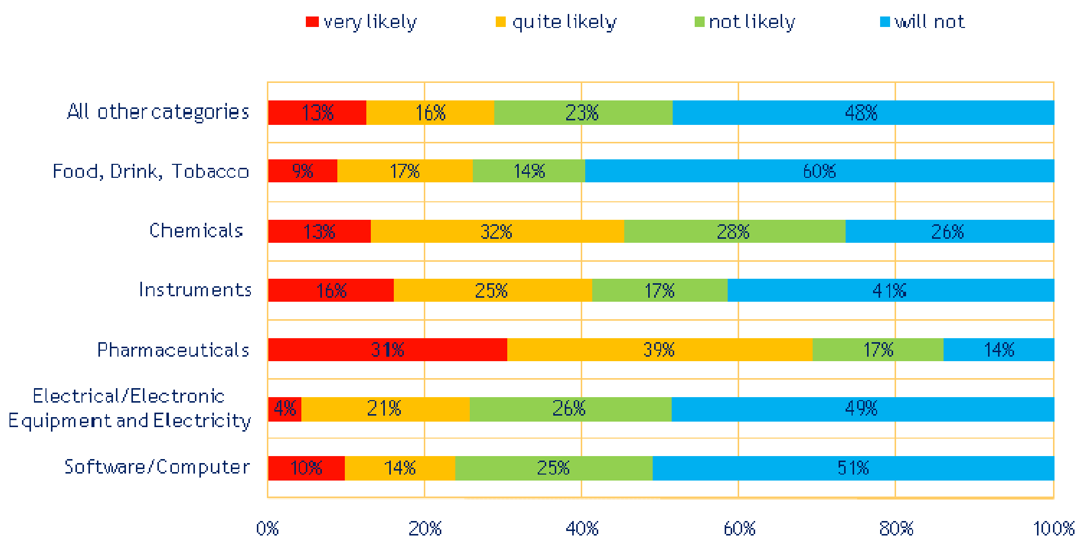
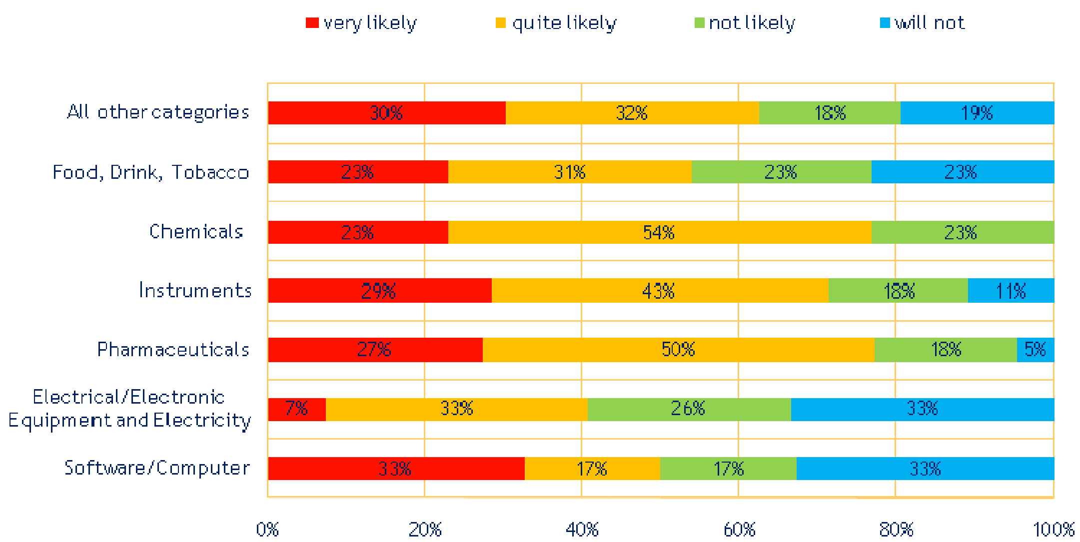


Figure 3.4 below shows the same chart for firms with PhD researchers already employed. More than half of firms in all industrial sectors (with the exception of the electrical and electronics sector) intend to increase the number of PhD researchers by 2013. This confirms the value PhD researchers bring to firms where they are currently employed.

Figure 3.4: Likelihood of increasing the number of PhD researchers - firms with PhD researchers

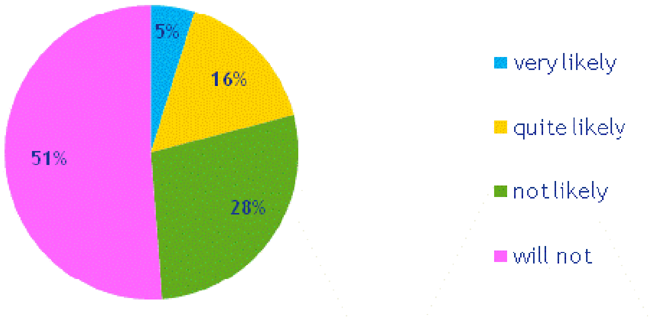


Again among firms that currently employ PhD researchers, demand is strongest (measured by the likelihood of employing additional PhD qualified researchers) in the pharmaceuticals (77%), chemicals (77%) and instruments sectors (72%). However, in the Software/Computer sector demand for PhD qualified researchers rises from 24% among all R&D performing companies to 50% for those already employing PhDs; in the electrical/electronic equipment sector it rises from 25% to 40% and in the food sector it rises from 26% to 54%.

3.1.2 Likelihood of increasing the number of newly qualified PhD researchers without enterprise experience by 2013

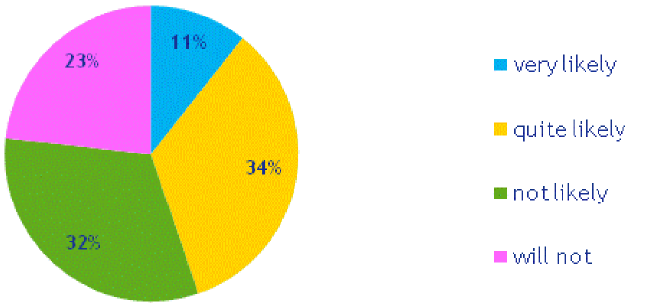
Figure 3.5 shows 21% of all R&D performing firms are likely to increase the number of newly qualified PhD researchers without enterprise experience in the period 2008-2013, however, more than half of firms will not increase the number employed and a further 28% are not likely to.

Figure 3.5: Likelihood of increasing newly qualified PhD researchers by 2013, all firms



Firms that currently employ PhD researchers are the most likely to increase the number of newly qualified PhD researchers by 2013. Figure 3.6 shows that 45% of firms with PhD researchers employed are likely to increase the number of newly qualified PhD graduates with no previous enterprise experience in the period 2008 to 2013, 23% will not do so and a further 32% indicated that they were unlikely to do so. Firms that currently employ PhDs researchers are significantly more likely to increase the number of PhD researchers by 2013 than the total cohort. Overall, there is a clear preference for firms to employ experienced PhD researchers rather than newly qualified PhD researchers.

Figure 3.6: Likelihood of increasing newly qualified PhD researchers by 2013, firms with PhD



The pharmaceuticals, chemicals and instruments sectors show the highest demand for newly qualified PhD researchers with 72%, 64% and 47% respectively likely to employ more PhDs by 2013. Demand for newly qualified PhD researchers is significantly lower in the electrical and electronic, food, drink and tobacco and the software and computer sectors with 11%, 35% and 39% respectively intending to increase the number employed in the same timeframe.

All sectors show a clear preference for experienced PhD researchers over newly qualified PhD researchers. The pharmaceuticals sector, however, has not made a big distinction between hiring experienced PhD researchers and newly qualified PhD researchers with 77% of firms that already have PhDs researchers likely to increase their numbers compared with 72% of firms prepared to recruit more newly qualified PhD researchers. Narrowing this down a little, however, 27% are very likely to increase the number of experienced PhD researchers compared to 10% that are very likely to increase the number of newly qualified PhD researchers.

3.1.3 Factors considered important when employing PhD qualified researchers

Firms with PhD researchers were asked to rank a given set of factors in order of importance when employing PhD qualified researchers. As shown in Figure 3.7 below, underpinning knowledge of the discipline was ranked as highly important by 68% of firms, followed by the relevance of the research topic (59% of firms) and knowledge of research approach, techniques and methods (57% of firms).

Figure 3.7: Important factors in employing PhD researchers, enterprises with PhD researchers employed

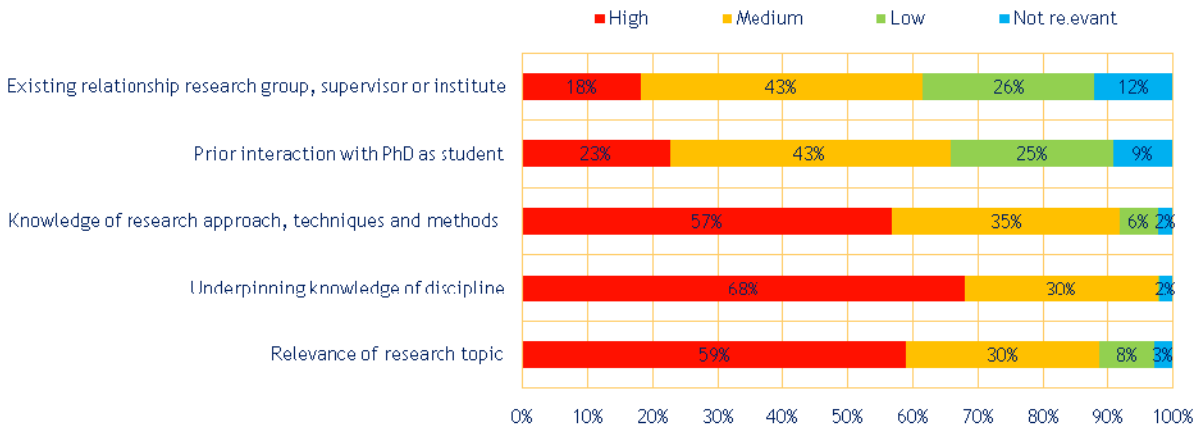
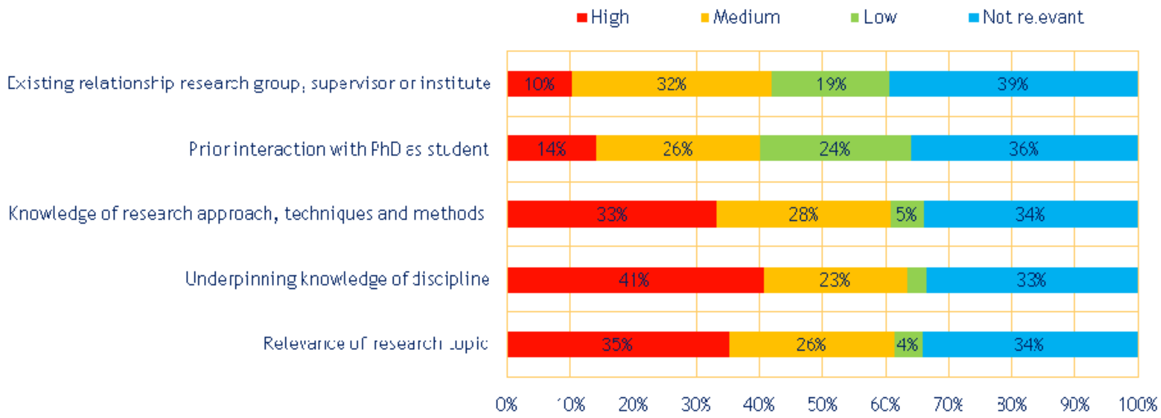


Figure 3.8 shows that firms not currently employing PhD researchers have ranked the same factors as highly important as companies employing PhD researchers:

- Underpinning knowledge of the discipline (41%);
- Relevance of research topic (35%);
- Knowledge of research approach, techniques and methods (33%).

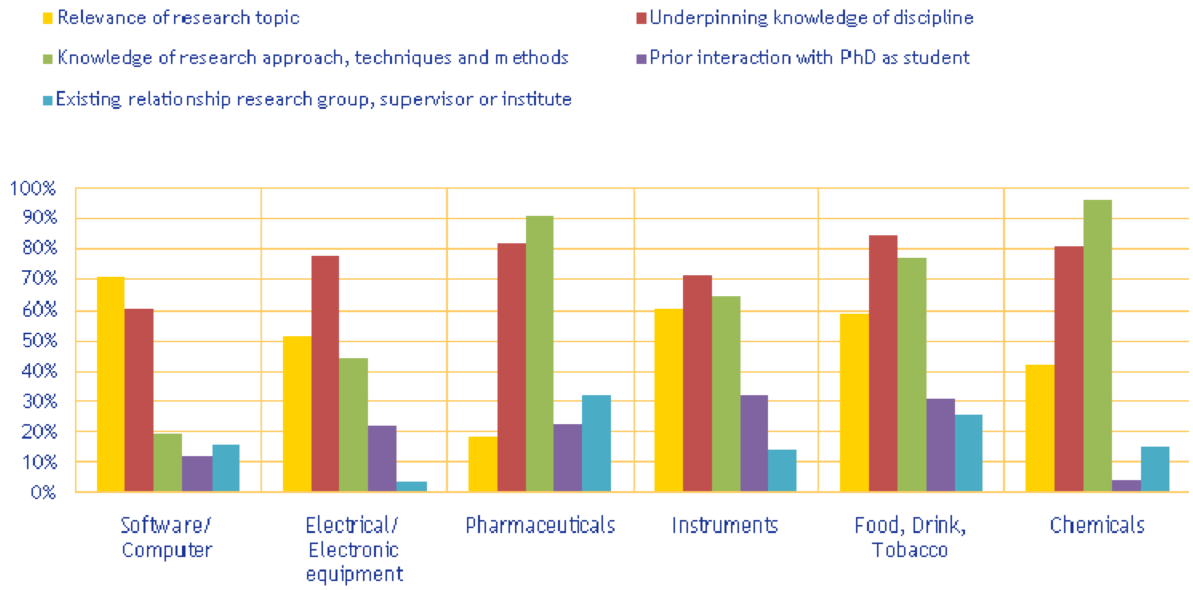
Figure 3.8: Important factors when employing PhD researchers, enterprises without PhD researchers employed



Over one third of firms not currently employing PhD researchers responded that the question was not relevant.

Figure 3.9 shows the factors ranked as highly important when employing PhD researchers for different industrial sectors for the subset of firms that currently employ PhD researchers. Knowledge of the research approach, techniques and methods associated with the field of research was considered a highly important factor by 96% of firms in the chemicals sector and 91% of firms in the pharmaceuticals sector. The underpinning knowledge of the discipline was ranked as a highly important factor by 60 to 85 per cent of companies in the industrial sectors below, with 85%, 82% and 81% of companies in the food, pharmaceuticals and chemicals sectors respectively that ranking it a highly important factor. Relevance of the research topic was ranked highly important by 71% of firms in the software and computer sector. An existing relationship with the PhD graduates research group was ranked highly important by 32% of firms in the pharmaceuticals sector.

Figure 3.9: Highly important factors when employing PhD researchers by industrial sector, enterprises currently employing PhD researchers

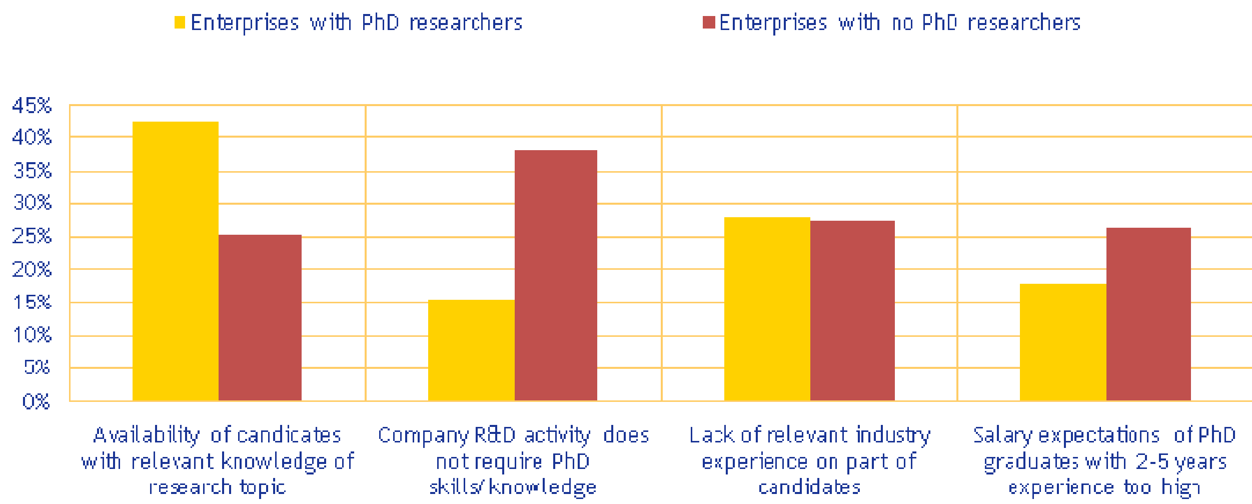


3.1.4 Highly important factors hampering the recruitment of PhD qualified researchers

Figure 3.10 shows the factors considered highly important in hampering the employment of PhD researchers for companies with and without PhD researchers employed. For enterprises with PhD researchers, 43% considered the availability of candidates with relevant knowledge of the research topic a highly important hampering factor, and a further 28% cited a lack of relevant enterprise experience on the part of candidates to be a highly important factor.

For companies not currently employing PhD researchers, 38% indicated that the company R&D activity does not require PhD skills or knowledge and a further 27% responded that a lack of relevant enterprise experience on the part of candidates was a highly important hampering factor.

Figure 3.10: Highly important factors hampering the recruitment of PhD researchers, firms with and without PhD researchers employed



3.2 Case studies from Enterprise

Companies from the ICT, pharmaceuticals (MNC and indigenous) and chemicals sectors provided case histories in order to illustrate representative career paths of PhD researchers in enterprise.

The case studies examined:

- the roles available to PhD researchers in enterprise
- the factors considered important when hiring PhD researchers
- the channels used to recruit PhD researchers
- comparison of PhD graduate career progression compared to non-PhDs in similar roles
- whether further demand is foreseen for PhD researchers in these enterprise sectors

3.2.1 Leading high technology manufacturer - ICT Sector

While the vast majority of employees are technicians and engineers, there are a small number of MScs and PhDs. The company recruits PhDs for process and yield engineering positions. There are higher proportions of PhDs working in manufacturing in the new fab and in the development side of

R&D as the research times are longer. The core R&D activities are digital health research, ICT and nano-technology. The majority of staff in the digital health area have a PhD.

Since 2003, 37 PhDs have been hired and of those 62% still work here, 41% have been promoted once and 8% have been promoted twice. 19 were hired as Process or Yield Engineers which is the equivalent of 8% of all Process and Yield engineers hired over the period.

The company recruits from a range of disciplines - computer science, biomedical engineering, social science, economics, statistics, clinical staff, technologists, physics, chemistry, engineering, visual computing, data analytics and cognitive computing.

A premium is paid for having a PhD. The starting salary is 40K per annum for a PhD, compared with 32K for a master's degree and 29k for a primary degree. The expectation is that someone with a PhD will be working at an equivalent level to someone with 5 years working experience.

The company tries to recruit Irish graduates and has formed strong relationships with the HEIs and research groups. There is no major issue attracting PhDs. The company looks to recruit PhDs when a niche area or specific set of skills is required for the role. All employees undergo the same behavioural interview process and need to meet the company 'fit' which includes soft skills such as tolerance to ambiguity and leadership skills. Generally, recent PhD graduates already have these skills. In enterprise the research path has been determined whereas in academia researchers have the freedom to decide their own path. PhDs need to be able to transfer and integrate in enterprise. The enterprise environment is more constrained than academia and PhDs employed need to be adaptable. They need to have the relevant skills aligned with the research topic.

When recruiting PhD graduates, technical expertise and an analytical mindset is most important as they are expected to challenge the status quo. There is in-house training to further develop the soft skills required.

The IRCSET Scholars program is a good model. A PhD student relevant to the research domain is taken on, completes an assignment and works in the company as part of their PhD. The company takes ownership of the IP. The IRCSET Scholar programme is regarded favourably and some people have joined the company on completion of the programme.

There is a student placement program for third level students in existence and PhD students could also be integrated into this program.

Recent feedback from HR is that in 2010 the ration of PhD/MSc: Grad hire will be a 40:60. However there is pressure corporately to significantly swing this with the newer technologies. In the new fabs that are coming online, the vast majority of Engineers to be hired will be taken on with a PhD – China, Israel.

3.2.2 Product Development Company – Indigenous Pharmaceuticals sector

This company specializes in bringing plant protection products (PPPs) and bio/pharmaceutical products to market. The company was set up to develop and register generic agrochemicals (and later biopharmaceuticals) on contract for clients. However, the strategic goal was always to develop own products (generics, super generics and bio similars) for direct sale by the company. One such product is on the market following an internal R&D programme, and a further 3 are in the pipeline.

The company's client base ranges from multinational agrochemical and bio/pharmaceutical companies looking to maximise patent extension opportunities on existing products and/or introduce new products, to virtual or early stage companies seeking to add new products to their portfolios. The company has a strong export focus (EU in particular), with 95% of sales to customers outside of Ireland last year. The company also provides consultancy services in Pharmaceutical Regulatory Affairs.

The company currently has 28 direct employees, the majority science graduates, 25% qualified to PhD level. It also employs up to 10 regulatory specialists on a contract basis.

The company employs PhDs in both technical and managerial roles. Of the 8 PhDs currently employed, 4 are in management positions including senior management, new product development and sales and marketing. The others are employed in method development and regulatory roles.

PhDs joining the company to take up technical positions are typically recruited with limited post-doctoral experience, but ideally have some enterprise experience. Due to specific training requirements, unless they have the required enterprise experience, PhDs join at the same level as graduates (i.e. analyst), and progress to "Study Director" level. However, their analytical, organisational and technical capabilities are generally stronger than those of a typical graduate, and so their progression to Study Director Level can be accelerated.

The knowledge of research approach, techniques and methods associated with the discipline is considered the most important factor when recruiting PhDs as researchers.

PhD qualified researchers are mainly recruited through websites or through contacts with the careers offices of the universities e.g. we recently recruited a DCU PhD who was working with a start-up in the UK through the DCU careers service.

The increased emphasis on in-house R&D and own product development will see more opportunities open up for people with PhD backgrounds. However, one observation might be that it is now relatively easy to recruit PhDs and there is a possibility that what was once a graduate position may become a PhD position, purely due to the availability of PhD candidates.

3.2.3 Product and Technology Development for adhesives and sealants – (Chemicals Sector)

The Dublin facility comprises a major manufacturing plant and a 100 person R&D facility. The R&D facility is a major Product and Technology Development group for adhesives and sealants.

PhD level Chemists are mostly recruited for positions in Product or Technology development. The primary criterion for recruiting PhD level chemists is always technical. The typical graduate today is well suited to enterprise, with good presentation skills and the ability to interact effectively with sales and marketing departments, customers etc. These skills can also be developed further via in-house training courses in project management and management training.

A premium is paid for having a PhD, PhD starting salaries are generally 20 % higher than paid to primary degree level candidates.

In R&D, chemists are normally recruited at PhD level. Product or Technology Development Chemists are the typical entry level positions. Senior positions are usually filled by internal promotion. Out of 96 technical staff, 46 have a PhD. Of the staff at chemist rank or above, 73% have a PhD.

On joining the company a PhD chemist is assigned to a team focussed on technology development or product development. Initially they work closely with a more experienced chemist or manager and eventually attain the necessary familiarity with the technology to function as a project leader in their own right. On attaining this proficiency they would be promoted to the first grade on the career ladder, begin managing projects themselves and may have technicians or other chemists directly reporting to them.

The next promotion on the career ladder is related to job responsibility and supervisory responsibility e.g. Group Leader in charge of 3- 5 scientific staff.

Further promotion is to management grades, e.g. Group manager in charge of a product development team (7 – 20 staff) or a technology area (7- 15 staff). These positions are normally filled by internal promotion , As in all companies, the number of higher positions in the facility is limited but opportunities exist for staff to relocate to other facilities in the global organisation which generally accelerates career progression. There are also opportunities to transfer into the production organisation particularly for individuals who have experience in Quality Assurance or Pilot plant production. In groups where a PhD is the norm all management also possess a PhD.

Technician positions are usually recruited at degree level and there are two promotional levels available within the technician grade. Promotions from Technician to Chemist can occur where the individuals' experience or personal excellence makes this appropriate. In these cases, the experience gained working in the facility is a large contributing factor.

Unlike Chemists, Engineers do not generally proceed to PhD level. In the areas such as Process Technology , Packaging development and Materials evaluation our recruiting requirements would be a good honours degree and 1- 2 years or relevant experience.

A primary degree in Chemistry provides a superficial knowledge of a wide range of topics within Chemistry. Graduates have limited laboratory experience and very limited project experience. They may be aware of a lot of systems/techniques/knowledge sources, but do not have the experience which comes from using them. At PhD level, individuals develop a number of skills:

a) A deeper knowledge of a narrow number of fields e.g. synthetic organic chemistry
b) Intimate familiarity with the underlying disciplines of scientific research
c) Familiarity with knowledge sources and ability to use these sources
d) Ability to structure a research project and to carry it out without the need for close ` supervision
e) The experience gained by working for a prolonged period on a project at the leading edge

It is unusual to find PhD graduates who have worked on research topics directly related to the development of adhesives technology or products. It is beneficial to have a good knowledge of Physical, Inorganic, Organic or polymer chemistry and to have some familiarity with materials science, polymer science, surface chemistry and production engineering concepts.

Given the general scope of adhesives technology, PhD graduates from a wide spectrum of areas can be successfully utilised. Fundamental to their success is a good knowledge of the underpinning science and ability to adapt easily to new problems.

Knowledge of research approach, techniques and methods associated with a scientific discipline is a very important aspect, but does not outweigh the basic relevance of the topic of PhD research e.g. a PhD in Biochemistry would find it difficult to adapt to mainstream work in the adhesives area.

Methods used to recruit PhD qualified researchers include the media, direct contacts to colleges, and occasionally executive search companies. More recently the majority of have come from scientific staff agencies coupled with unsolicited CVs already on file. The latter probably arise from contacts between recently qualified PhD's and our new staff. Newspaper advertisements have been unproductive over the last few years and are used less frequently. The majority of PhDs recruited are from Irish universities, but would recruit from other countries if a specific skill set was required and was not available here.

Over the past three years recruitment has been at a high level (5- 7 positions /year). For the next two years, as a consequence of the contraction of the global economy, probably only staff who leave will be replaced. Following that, there will be a steady retirement at senior levels which will provide opportunity for internal promotions and replacement positions at entry level. Opportunities to add new capabilities and responsibilities to the company's research portfolio will continue to be sought and success in this area could lead to an additional recruitment of teams of 3- 5 PhD s to start up new venture areas.

3.2.4 Pharmaceutical company

In the process development part of this company, PhDs are hired in experienced and expert scientific roles. Some leadership roles (requiring experience) are at PhD level. Annual recruitment is about 5–10 people and only 10-20% of that is at PhD level. The remainder of the plant activity has very low need for PhD level staff.

The typical career path for a PhD researcher entails two-three years in the lab followed by a period as a supervisor of less experienced staff. There is a two path career ladder so that PhDs can develop on the managerial supervisory line as well as the technical role. Usually, people need to broaden out beyond their technical base in the process development environment to get beyond Associate Director level (10 years + on top of PhD).

PhD candidates are not always required for these positions. Many engineers (biochemistry and chemical engineers) are also hired. Often experienced degree and Master's level graduates can do these roles.

Pure researchers are not hired as our focus is on process development where the activity is on the latter stages of the R&D continuum. The factors considered important when recruiting PhD researchers are ranked below.

1. The fundamental underpinning knowledge of their discipline (high);
2. Knowledge of research approach, techniques and methods associated with the discipline (medium);
3. The relevance of their research topic (low).

PhD qualified researchers are recruited through the media, relationship with universities /PIs etc). The expectation is that there will be 5-10% increase in the number of opportunities arising for PhD researchers.

Chapter 4 – Recommendations

The ASC's recommendations are targeted firstly at developing a cohesive strategy for aligning PhD skills with enterprise needs and facilitating mobility between the sectors and secondly at developing the skills and knowledge of PhD graduates and postdoctoal researchers to create new opportunities in existing and new enterprise. In its discussion the Council is mindful of the current economic environment and therefore of leveraging existing programmes and structures to achieve the outcomes.

Cohesive Strategy for Aligning PhD Skills with Enterprise Needs

A Prioritisation of research funding

The increases proposed in the SSTI in advanced researcher numbers and the aim to see a significant movement of advanced researchers to the enterprise sector, underscored the need for the development of structured PhD programmes. The results of the BERD survey clearly indicate that the demand for PhD qualified researchers is concentrated in specific sectors of the economy. This should be reviewed on a continuous basis.

The software and computer related activities sector, the R&D sector and electrical and electronic equipment sector together account for 69% of all research personnel while the highest ratios of PhD-qualified researchers to non PhD qualified researchers are in the pharmaceutical and chemical sectors and the food sector. In absolute terms, the other services sector, pharmaceuticals, chemicals and electrical and electronic sectors have the most PhD researchers employed.

While a robust, world class research system that underpins growth in the medium to long term requires open competitive research funding, there also needs to be strategic prioritisation to meet the medium to long-term needs of the economy. The development of structured graduate education programmes in the higher education institutions is supported by the HEA. This is done through the Strategic Innovation Fund, the PRTLI and the Research Councils in specific disciplines or in multidisciplinary areas to drive collaborations between institutions and create critical mass in areas aligned with research strengths. The development of fourth level education should also be aligned with the sectors of the economy, both public and private, where PhDs are, or are expected, to be employed. The Council understands that these additional criteria in the allocation of competitive funding will have a significant impact in how institutions develop future structured PhD programmes but believe that it is important to achieving the social and economic impact of the SSTI.

Recommendation 1:	**Funding for structured PhD programmes should be broadly aligned with the sectors of the economy where there is a strong demand for PhD qualified researchers.**
Responsibility:	**HEA and HEIs**

B Structured Graduate Education Programmes

Structured education programmes are the proposed new approach to PhD education and training and refer to recent initiatives undertaken by Higher Education Institutions individually and the HEA to provide structured relevant professional skills training to enable PhDs to develop their careers in diverse sectors of the economy.

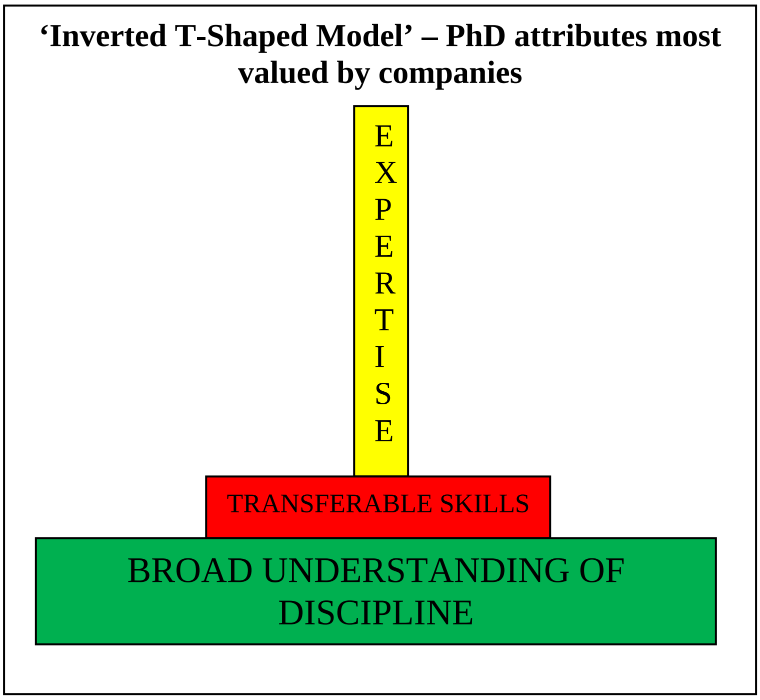
The traditional model of PhD education could be described as being similar to the "apprenticeship model" where lone or small groups of students are situated within a single higher education institution. The primary focus is towards their PhD thesis and if they receive any generic/transferable skills training then this is an "extra" and not part of their core training. Typically there is funding for three years while the average PhD period is around four years.

The new model proposes a more structured programme with the possibility of more than one supervisor (doctoral committees) and that these may be based in more than one institution. This model was proposed in 2005 by the IUA in 4th Level Ireland. The focus will still be the PhD thesis and contributing a unique body of knowledge but the generic and transferable skills will be embedded in their education and training. This new approach to PhD education requires changes at a number of levels within the HEI system – systematic changes within the overall structures, changes at an institutional level, changes within colleges/schools and changes at research topic or theme level.

The BERD Survey 2007/2008 identified the most important factors for enterprise when employing PhD researchers:

- Broad understanding of discipline and of fundamental and underpinning technologies;
- Knowledge of research approach, techniques and methods; and
- Relevance of a research topic (specialist expertise).

Based on the response the diagram (Figure 1) below illustrates the model for PhD education that enterprise look to when recruiting PhD qualified researchers. The broad knowledge of the discipline is critical to the value of PhDs for enterprise and it is an attribute that is very difficult for companies to develop in-house. In contrast, transferable skills such as project management, communication, etc, can be developed through in-company training. Therefore, PhD graduate education programmes should focus efforts on developing a student's understanding of the discipline (development of transferable skills, though important, should not come at the expense of this understanding) as well as in-depth knowledge of research approaches, techniques and methods. Quality has always been a cornerstone of PhD awards and the Council acknowledges that quality should continue to be the fundamental criterion.



Recommendation 2: **Structured PhD programmes should embody the "Inverted T" shaped model for education and training of PhD students.**

Responsibility: **HEA and HEIs**

Recommendation 3: **HEIs should continue to engage with enterprise and should adopt systematic and formal consultation with enterprise in the development of Structured PhD programmes at discipline level within the institutions, ideally with the involvement of enterprise boards to oversee structured programmes, where appropriate.**

Responsibility: **HEA and HEIs**

C Visibility of PhD Pipeline

The higher education institutions and the HEA have adopted a new approach to PhD training and education that will prepare graduates for careers in the enterprise. It is important that the enterprise community are aware of these positive developments and the skills and knowledge with which graduates will emerge. Also, when recruiting researchers, employers attach importance to the relevance of the research topic and the knowledge of research approach, techniques and methods. The availability of candidates with relevant knowledge of the research topic was cited as a highly important hampering factor by 43% of companies with PhD researchers employed. Therefore it would be very useful if employers or potential employers could easily access information on the number of PhD students in specific disciplines and the focus of their research. This would assist companies that employ significant numbers of PhD researchers to identify potential candidates.

Recommendation 4: A user-friendly, centralised system should be developed to allow employers or potential employers to access information on the number of PhD students in the pipeline and the broad theme of their research.

Responsibility: HEA

D IRCSET Enterprise Partnership Scheme

The Irish Research Council for Science, Engineering and Technology (IRCSET) Enterprise Partnership Scheme was developed on a pilot basis in 2004 and links with private enterprise and eligible public bodies to co-fund postgraduate scholarships and postdoctoral fellowships. The Scheme offers researchers the opportunity to gain additional beneficial experience and insight into the commercial arena while completing their research and an enterprise mentor is appointed to the student. It provides enterprise with access to researchers and the opportunity to build links with relevant academic research groups. One of the main benefits of the scheme is that it facilitates the establishment of new relationships and the strengthening of existing relationships between enterprise and academia while offering financial support to researchers at an early stage of their career development. In addition the scheme ensures that PhD students are funded to work in areas of direct relevance to the enterprise sector and that on completion the PhD graduates have the skills required by the companies for future employment. The Council believes that this programme should be scaled up and that the appropriate resources be made available to increase the programme's capacity. In particular increased capacity should be linked directly to the achievement of SME participation targets in the scheme. This is an excellent model which is very highly regarded by enterprise on the basis that it is simple and effective. Such schemes need to be significant sources of PhD education going forward.

One of the issues that will arise in implementing this recommendation is the Intellectual Property (IP) arrangements that would be in put in place around such an initiative. The Council recognises that IP arrangements are of fundamental importance to the commercialisation of publicly-funded research and therefore any IP arrangements should bolster the national policies on the protection and exploitation of IP. The ASC is aware that Forfás, at the request of the DETE, are undertaking a review of the IP arrangements on publicly-funded research in Ireland. The Council suggests that the IP review looks to produce a mechanism to protect and exploit the IP from publicly funded research that is streamlined and easy to engage with. This should be structured in a way that encourages enterprise, entrepreneurs and others who have the skills to exploit IP which delivers value to the creators of the IP and creates economic impact. This would have the outcome of facilitating more PhD students to do more R&D with enterprise.

Recommendation 5:	**The Council strongly endorses the Enterprise Partnership Scheme and recommends that resources are made available to scale up the programme**
Responsibility:	**HEA and HEIs**

E Doctorates for Researchers in Enterprise

In Europe today doctoral studies are in a process of change, for many reasons, reflecting the need and recognition to adapt research to meet the challenges of a global labour market, technological advances, new profiles and demands of doctoral candidates and policy objectives of European governments[45]. The most predominant component of the doctorate is evidence by candidates having to prove their ability to perform original and independent research. However, for many reasons including increased global competition for jobs, Ireland has been developing its' doctorate programme whereby a broader range of skills training are available for PhD students to prepare them with a well rounded skill-set valuable for various sectors of the economy.

Responding to similar challenges, Demark has developed an Industrial PhD programme. The industrial PhD programme is as its' name suggests is a programme whereby an employee of enterprise earns their PhD based on research relevant to their enterprise. It currently accounts for 7% of all PhD graduates in Denmark and the target has now been raised to 10%. The main aims of the programme are to:

- Upskill researchers working in enterprise;
- Build know-how, knowledge dissemination and interaction between academic and research institutions and enterprises.
- Ensure commercialisation of new know-how and research, including development of knowledge and technology based enterprises.

45 Doctoral Programmes for the European Knowledge Society. European University Association (2005).

Evidence from the evaluation of the Danish Industrial PhD programme suggests that this programme provides the student with the ability to inter-collaborate and nurture project management and organisational skills. It gives them experience in patenting, commercialisation and dissemination of their research. The Industrial PhD programme in Denmark contributes to sending many highly educated people out into the business world and often in R&D management positions. It contributes to creating new knowledge of enterprise relevance and over 70% of enterprises that participated commercialised the research undertaken. It is an extremely effective network promoter between universities and enterprises. It provides enterprises with the opportunity to liaise with university staff and use their expertise for the development of enterprise. Overall, the Industrial programme has created a great deal of satisfaction for all involved parties. It also fosters an entrepreneurial culture with 8% of the PhD graduates establishing their own business. The cost of the programme including the employee's salary is co-funded by the Enterprise partner and the programme promoter.

The Council believe that this model should be adopted in Ireland as it will support a number of key objectives of the Smart Economy including the commercialisation of research from third level institutions and the mobility of researchers between the HEIs and enterprise. The impact of this initiative would be enhanced by aligning it with the enterprise-HEI collaborative initiatives including SFI CSETs and Enterprise Ireland's Competence Centres.

Again one of the issues that will arise in implementing this recommendation is the IP arrangements and the Council would again recommend that the Forfás IP Review consider the most effective IP arrangements.

Recommendation 6: Ireland should develop an Enterprise PhD programme building on the model of the Danish Industrial PhD programme.

Responsibility: HEA with input from enterprise agencies and the HEIs

F Enabling PhD researchers to create new enterprise opportunities

While there are opportunities for PhD researchers within existing R&D-active enterprise the Council believes that there is potential for PhD graduates to stimulate new enterprise opportunities. A key feature of the Smart Economy approach is to "build the innovation or ideas component of the economy through the utilisation of human capital – the knowledge, skills and creativity of people – and its ability and effectiveness in translating ideas into valuable processes, products and services"[46]. As well as their specialist knowledge and broad disciplinary knowledge, PhD graduates must demonstrate an aptitude for original thought and problem solving and these attributes should

46 Department of An Taoiseach, "Building Ireland's Smart Economy", p7

enable a certain cohort to develop careers as entrepreneurs. The Technology Transfer Offices within the HEIs, supported by Enterprise Ireland, provide support and training to researchers to identify and capture the intellectual property and support to entrepreneurs and start-ups to commercialise IP. The Council recommends that Technology Transfer Offices, supported by Enterprise Ireland, should develop a coherent and integrated programme of support and training for PhD students that enables them to identify and exploit commercial opportunities arising from their research with the agreement and support of their supervisor(s). While a period of postdoctoral research would probably be necessary to bring the research to the point where it is ready to be commercialised, the ASC believes that the groundwork should be laid during the PhD education.

Recommendation 7: Beginning with the PhD education and training period and continuing through to early postdoctoral research stage there should be an integrated programme of support and training specifically targeted at PhD students and early postdoctoral researchers to enable them to commercialise their research.

Responsibility: Technology Transfer Offices and Enterprise Ireland

Annex 5: Danish Industrial PhD Programme

The industrial PhD programme began in 1970 and the student earns their PhD in collaboration with enterprise. The programme is targeted at Masters Level students and business that can professionally support a three year business-oriented R&D project.

The aim of an industrial PhD programme in Ireland would be to develop the business aspect of the research as well as high level research skills. In effect, the programme would aim to develop world class researchers with good business acumen.

Approximately 7% of all PhDs in Denmark are industrial PhDs. The Danish Council for Technology and Innovation Action Plan (2007 – 2010) has set a target to double the number of industrial PhD's by 2010 which equates to 150 Industrial PhD projects per annum by 2010. This action plan recommends that regular PhDs also be afforded the option to spend time in enterprise. The Industrial PhD programme is pitched at the highest calibre of candidates in Denmark. Denmark has been evolving its doctorate programme to incorporate a broader range of transferable skills to prepare them for jobs in enterprises in different sectors of the economy.

Funding

All Industrial PhD projects are co-financed by the Danish Agency for Science, Technology and Innovation (DASTI), and the enterprise hosting the Industrial PhD student. Expenses for the enterprise, university fees and third party supervision are shared between the host enterprise and the DASTI. The main aims of DASTI are to:

- Build up know-how, knowledge dissemination and interaction between academic and research institutions and enterprises.
- Ensure commercialisation of know-how and research, including development of knowledge and technology based enterprises.

The DASTI reimburses up to 50% of the salary of the Industrial PhD and the cost of the university. This means the industrial PhD programme in Denmark is less expensive on the public purse than that of the conventional PhD student as the cost is shared with enterprise. The Industrial PhD programmes are spread across all the universities in Denmark, but the highest proportion of Industrial PhD projects are in the Technical University of Denmark where they account for almost 40% of PhDs.

The industrial PhD evaluation report undertaken in Denmark and summarised in this report is based on projects from 1992 onwards.

Reasons for Success

1) User-driven

- Enterprise owns the project;
- The research project originates from an enterprise relevant problem;
- PhD divides his/her time between enterprise and the university;
- Enterprise selects university for collaboration;
- Enterprise owns the IP.

2) The research education is at a highly specialised level

- Universities ensure the Industrial PhD is on par with traditional academic course.

3) Quick Case work

- 30 days from time of application to decision of support.

Industrial PhD Profile

Entry requirement is a Masters Qualification or appropriate experience, such as a significant publication record. The technical sciences comprise the largest proportion of participants on this programme.

Recruitment

Finance, business services and manufacturing comprise 90% of the types of enterprises employing Industrial PhD graduates.

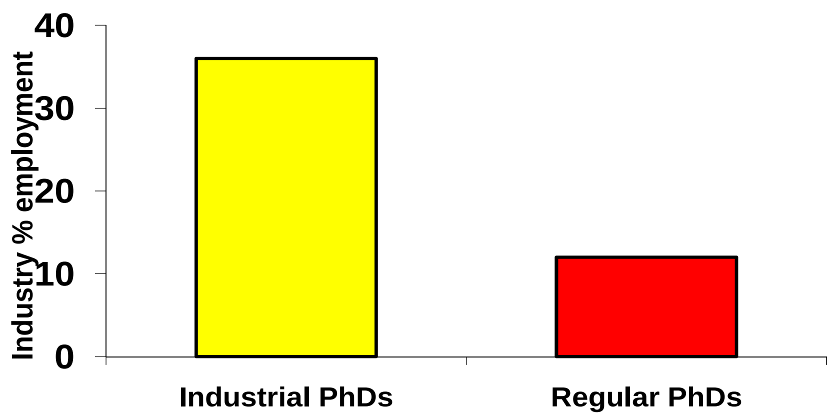


Figure 2. The percentage of Danish Industrial PhDs and Danish Regular PhDs employed in industry

Enterprise employs three times more industrial PhD graduates than regular PhDs.

Enterprise Participants

Enterprises must have research experience to participate in this programme. Not surprisingly, research-intensive firms are the most active in this programme. The programme is directed towards enterprises that can provide professional support towards a three year business oriented project. The number of enterprises participating in the project increased from 35 in 2002 to 53 in 2005.

Benefits of Industrial PhD Programme

Employment Benefits:

The Danish evaluation indicates that 8% of Industrial PhDs are employed in top management positions (n=450) compared to 4% of regular PhDs (n=7336) after 9 years in the marketplace.

Graduates of the course do not encounter problems in finding employment. Many Industrial PhD students commented that the combination of research and professional experience makes gaining a PhD more attractive. The programme allows the student to understand business needs. The networks built up through the Industrial PhD training provide contacts that the PhDs can easily turn to share ideas and opinions.

The graduate should have increased mobility with university and enterprise training and experience. This should afford more opportunities and allow the researcher to transcend the traditional barriers to mobility.

Based on results from the 'Danish PhD Programme' Graduates of the programme would be more likely to be employed within enterprise or to create new start-ups and spin-outs. Approximately 8% of Industrial PhD graduates develop their own businesses.

Benefits for Sectoral Mobility:

There is mobility for Industrial PhD's within different industry sectors. One third of Industrial PhD graduates are retained in the enterprise where they completed their PhD. The other two-thirds are employed in other enterprise sectors and often switch trade.

Benefits for Enterprise:

Enterprises expressed satisfaction with their participation in the Industrial PhD projects. They experienced concrete results not only by way of increased revenue, exports, market share and annual sales but also by way of such long-term impacts as issued patents, license sales, and other types of innovation-promoting results. Approximately 40% of respondent enterprises said that the project led to new or improved products. Half of enterprises had more than 20 years R&D experience before participating in this programme, indicating the importance of the programme to established R&D enterprises.

The enterprises experienced a tighter network within the domain of public research in Denmark and abroad. At the same time, a significant competence development takes place at the enterprise through the sharing of theoretical professional knowledge and practical improvements of processes, services, and products. The enterprise can initiate more risky and challenging projects that it may have shied away from in the past. Almost three quarters of enterprise participants applied the research results. It is a way of undertaking low cost research with great effect. Approximately one quarter of enterprises hire new employees as a result of participation and small enterprises are the ones that hire most new employees as a result. Ninety six percent of participating enterprises experience an expansion of their research network and they listed network expansion as having a real impact in a number of areas, most importantly general skills building. New products and production processes follow (22%) and improvements to existing products and production processes 21%. Right, Kjaer and Kjerulf (2003)[47] reported on an investigation into 50 enterprises that participated in the Industrial programme in 2002 and discovered a little over half of respondents reported an estimated employment effect of 3-4 employees and the employment effect is positive for 28% of enterprises.

Benefits for Universities:

Universities in Denmark achieve an improved sense of the research-relevant needs of the enterprise through the industrial PhD programme. This leads to improved skills on both theoretical and practical levels at the university, but also through intensive networking with private enterprises, which continues even after an Industrial PhD project has ended. It also increases the number of PhD graduates and publications from the university.

In Denmark the expense on the public purse for Industrial PhD projects is less than half of a regular PhD. This is a cost effective way of increasing the number of research education posts and increasing the number of doctoral researchers in enterprise.

47 Right, Kjaer and Kjerulf (2003). Study of aspects of the support effectiveness in the Industrial PhD programme

Annex 6: The IRCSET Enterprise Partnership Scheme

- Established on a Pilot Basis 2004
- 3 year PhD / 1 year MSc Awards
- €24,003 per annum
- Enterprise Partner contributes 1/3
- 2 year Postdoctoral Fellowships
- Developing researcher's transferable skills
- Exposure to commercially orientated research environment
- Developing links between academic research groups and research orientated companies
- Maximising potential for company innovation
- Open to SME's, larger companies and multinational companies
- Commitment to co-fund at a rate of one third for the duration of the award.
- More than a financial contribution
- Capacity to provide professional guidance / mentoring as well as access to experimental facilities or data.
- Provide Enterprise mentor
- Relationship with the academic supervisor.
- Intellectual Property Agreement with the participating Higher Education Institute must be in place before the award is offered.
- Public bodies / agencies or other publicly funded organisation are eligible where they cannot fund the full cost of the scholarship (with administration of the award through IRCSET).

Appendix A Members of the Taskforce

Council Members

Prof. Anita R Maguire, Department of Chemistry, UCC

Dr Reg Shaw, Chairman, Health Research Board

Additional Members

Dr. Barry Kennedy, Intel Ireland

Dr. Seamas Grant, Henkel

Dr. Brendan Hughes, Wyeth

Dr. Mary L Martin, AGI Therapeutics plc

Dr. Martin Lyes, Enterprise Ireland

Dr. Leo Bishop, IDA Ireland

Dr. Graham Love, Science Foundation Ireland

Mr. Martin Cronin, former CEO, Forfás

Research and Technical Support

Ms Helena Connellan, Forfás

Mr Maurice Dagg, Forfás

Mr John Dooley, Forfás

Ms Karen Hynes, Forfás

Appendix B Members of the Advisory Council for Science, Technology and Innovation

Council Members

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Prof Anita R Maguire, Prof of Pharmaceutical Chemistry, Director, Analytical and Biological Chemistry, Research Facility, University College Cork

Ms Mary Cryan, Cryan Consulting

Dr Sean Baker, Independent Consultant

Ms Bernadette Butler, Managing Director, Good 4U Food and Drink Co. Ltd.

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Ms Marion Coy, President. GMIT, Galway

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