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Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university

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ABSTRACT

Based on data collected through a complex survey of science and engineering PhD graduates from a UK research-based university, this paper examines the different types of careers and to what extent different types of competences acquired from doctoral education are regarded as valuable in the different career types. The results show that employment outside the conventional technical occupations is the main destination for the survey respondents. This career type is not only successful at retaining its members, but is also the destination of the other career types. Moreover, different types of competences from doctoral education are regarded as relatively more valuable in different career types: knowledge directly tied to subject areas is regarded as more valuable in academia/public research; both knowledge directly tied to subject areas (but more general type of knowledge rather than specialist knowledge in PhD topics) and the more general and transferable skills are regarded as valuable in technical positions in manufacturing; and the general and transferable skills are regarded as more valuable in employment outside the conventional technical occupations. In absolute terms, general analytical skills and problem solving capability acquired from doctoral education are perceived as valuable in all three career types.

1. Introduction

In the early 1990s, in the publications "Science and Technology Policy" (OECD, 1991) and "Technology-Economic Programme: Technology and the Economy" (OECD, 1992), the OECD was concerned with the prediction among several member countries of a future shortage of scientists and engineers and its possible impact on the economy. This prediction was based on both the belief that there would be an increased demand for scientists and engineers and the perceived decline in students' interests in science and engineering.

This concern about a future shortage of scientific labour force was echoed in policy reports in a number of countries. In the UK, the 1987 Department of Education and Science White Paper stated that the demand for highly qualified manpower outstripped supply and called for an increase in the number of graduate scientists and engineers (Department of Education and Science White Paper, 1987). In the USA, in 1991, the Bureau of Labour Statistics developed a projection of the labour force covering 1990–2005. The projection indicated that for scientists, engineers and technicians as a group, demand could increase by up to 59% (Braddock, 1992). Alternatively, a 1990 study by the National Science Foundation projected that there would be a shortfall of 675,000 graduates in natural science and engineering by the year 2006 (Finn and Baker, 1993).

The concern raised during this period about the future shortage of scientists and engineers and the possibility that their technical knowledge and talent may not be properly exploited was justified by the belief that having qualified scientists and engineers working within the boundaries of the conventional scientific and engineering occupations was a key factor contributing to national technological competitiveness and economic growth (Dosi et al., 1994; Freeman, 1992). Consequently, policy responses included a series of programmes for training scientists and expanding the number of PhDs in science and engineering in member countries (OECD, 1991).

More than a decade later, policymakers are still concerned about the shortage of scientists and engineers due to the continued lack of interest in science and engineering among students, but this time the concern is not just about how to keep science and engineering graduates in their conventional occupations. The contemporary argument is that, in the new economy, the basis of competition has changed and is increasingly driven by knowledge and intangible assets, with knowledge production becoming more widespread and widely distributed across a host of new places and actors, in many cases outside conventional technical occupations (David and Foray, 2002). Therefore, in contrast to the

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attitudes in the late 1980s and the early 1990s, policymakers have begun to recognise that one of the reasons for supporting the production of larger numbers of science and engineering graduates is that, in the new economy, with more and more sectors adopting new technologies, the demand for scientists and engineers is increasing outside the conventional boundaries of science and engineering occupations in order to adopt, produce and diffuse knowledge efficiently (The Dearing Report, 1997; Foray and Lundvall, 1996; OECD, 2000). Moreover, with structural change in the economy, including the decline of manufacturing and the increasing importance of services, the amount of highly skilled personnel such as scientists and engineers in the service sector is becoming increasingly significant (Cervantes, 2001; Lavoie and Finnie, 1998; Lavoie et al., 2003), as many jobs and functions are displaced or outsourced from traditional manufacturing sectors (Miozzo and Grimshaw, 2006). Indeed, the 2002 Sir Gareth Roberts' review of supply of science and engineering skills in the UK, entitled "SET for Success", clearly stated that many scientists and engineers make contributions to the economy through employment in many sectors, not only through working in industrial R&D.[1]

Hence, regardless of the change in rationale, the demand of scientists and engineers has been increasing over the last decade. In the UK, such demand has been re-affirmed in the 2008 White Paper entitled "Innovation Nation" (Department for Innovation, Universities & Skills, 2008). However, most of the discussions in existing policy statements or reports are based on science and engineering (S&E) graduates. Whether scientists and engineers at doctoral level are experiencing the same trend is a matter of empirical research. Traditionally, doctoral education was regarded as a passport to academia or public research organisations. This is visible in the Harris Report (1996) in the UK which stated that because many postgraduate research students might go to work in higher education institutions, higher education institutions should provide them with proper training related to teaching. However, with the huge increase in the number of people with doctoral qualifications, many studies have expressed concerns about the lack of job opportunities for science and engineering (S&E) PhDs in academia or public research organisations (Dany and Mangematin, 2004; Enders, 2002, 2005; Fox and Stephan, 2001; Giret and Recotillet, 2004; Mangematin, 2000; Martinelli, 1999; Robin and Cahuzac, 2003; Stephan et al., 2004). Whether this traditional career type is the dominant one for S&E PhD graduates is a question open to empirical research. Thus, given the change in the rationale for the demand of scientists and engineers and the implications for S&E PhDs, this paper intends to explore empirically the career types of S&E PhDs and to investigate whether S&E PhDs are most likely to be employed within or outside the conventional S&E PhD occupations. Also, the paper studies to what extent the different types of knowledge and skills acquired from S&E doctoral education are perceived as valuable in different occupations.

The paper is organised as follows. Section 2 reviews the types of careers for S&E PhDs. Section 3 explores the knowledge and skills acquired from doctoral education and to what extent they might be relevant to different career types, paying particular attention to the distinction between the conventional S&E PhD occupations and the potentially increasingly significant employment outside the conventional S&E PhD occupations. Section 4 discusses the data used in the analysis, which is based on a complex survey, the analysing methods and measures. Section 5 presents the results and Section 6 summarises the discussion and conclusions.

[1] Document online available at: http://www.hm-treasury.gov.uk/ent_res_roberts.htm (accessed 24 January 2010).

2. Careers of S&E PhDs

Scholars in innovation studies have pointed out the contributions of S&E PhD personnel to the economy. Pelz and Andrews (1966) stressed that PhD and non-PhD personnel differ significantly in their motivations and the quantity and quality of their output. Mangematin (2001) also pointed out the special nature of doctoral manpower because its members, on the one hand, are trained in universities and contribute to production of new knowledge and, on the other hand, serve as an important channel for knowledge transfer from academia to industry if they enter industry after doctoral education. Indeed, it has been argued that one of the most significant benefits to the economy from public funded basic science is highly trained manpower for industry and government through S&E doctoral education (Larédo, 2007; Martin and Irvine, 1981; Mowery and Sampat, 2005; Pavitt, 1991). These arguments suggest that PhDs may bring either the most up to date scientific knowledge they have produced or their capabilities in producing such knowledge into industry and result in knowledge spillovers through mobility across different employment contexts (Almeida and Kogut, 1999; Madsen et al., 2003; Rosenkopf and Almeida, 2003). This means that the extent of S&E PhDs' employment in industry has an impact on how academic research is transferred to industry.

The extent to which S&E PhDs are employed in industry shifts over time and seems to become increasingly significant. Martin and Irvine (1981) surveyed PhDs trained in two UK radioastronomy observatories (Jodrell Bank and Cambridge) between 1945 and 1978. Their data revealed that at the time of survey, first jobs for respondents were 55% in academia, 22% in government and 17% in industry and the most recent jobs were 46% in academia, 29% in government and 20% in industry. This indicates that throughout the period, career patterns for radioastronomy PhDs in the UK were rather stable. Stephan (1996) showed that in the US, up to 1991, academia remained the largest employment sector for doctoral scientists although the proportion was decreasing. Industry was the second largest employment sector for doctoral scientists and the proportion was increasing. Stephan et al. (2004), based on data from the US Survey of Doctorate Recipients from 1973 to 1999, further pointed out that for those who have left graduate schools for more than 5 years in all science and engineering fields, employment in industry grew so rapidly that by 1989, industry surpassed the tenure-track academic sector as the most common employment sector for S&E PhDs and by the mid-1990s, it surpassed all types of academic employment. A UK survey targeting the PPARC (Particle Physics and Astronomy Research Council) sponsored PhD students (DTZ Pieda Consulting, 2003) estimated that 6–8 years after awards ended, in 2003, 15% of the sponsored students were either in permanent university research positions or in government/public sector research positions and 54% were in the private sector. Ender's (2002) German case, based on a survey of three cohorts of German doctorates (1979/1980, 1984/1985, 1980/1990) in 1999, reported that in the long run (15–20 years after graduation), only 40% of mathematics graduates and 20% of electrical engineering graduates were in higher education. These studies imply that in many counties, academia is becoming the secondary employment sector for S&E PhDs, while industry is gaining its dominance as the major PhD employment sector.

Because these observations may indicate an employment pattern that diverges from the traditional expectation that PhDs are trained to become academics, this has led scholars to discuss a number of issues. These include: the incentives for doing a PhD (Mangematin, 2000), expectations and realities regarding employment (Fox and Stephan, 2001; Mangematin, 2000), value of the doctoral research training (Enders, 2002, 2005), employability of people with a doctoral degree (Dany and Mangematin, 2004), deter-