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Job mobility of science and engineering PhDs: ?movers? and ?stayers? and implications for knowledge flows to industry

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we call ?hybrid? labour market features, with strong occupational labour market features. We also find a distinctive gap in knowledge base between the conventional technical occupations and the new types of employment for S&E PhDs in the knowledge economy. Hence science doctorates? job mobility itself might not be an adequate indicator for academic knowledge flows to industry in the knowledge economy. Furthermore, the reluctance of many academic researchers to move to industry suggests that in order to foster knowledge transfer from academia, it may be more effective to encourage academics? temporary rather than permanent job mobility to industry. The paper suggests policy efforts could focus on encouraging academics to participate in research collaborations with industry with higher academic value and on supporting firms to take a more active role in seeking academic partners to help with more specific technical problems.

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Abstract

Drawing on a survey of science and engineering PhDs from a UK research-based university, this study uses job mobility histories to explore the labour market of science and engineering PhDs. We derive distinctive labour market features for different career types of science and engineering PhDs. Those employed in academic/public research experience what we call 'dualist' labour market features, with internal labour markets but strong segmentation between core and peripheral workers. Those in technical positions in private sector manufacturing experience relatively more 'structured' internal labour market features. Finally, those employed outside the conventional technical occupations experience what we call 'hybrid' labour market features, with strong occupational labour market features. We also find a distinctive gap in knowledge base between the conventional technical occupations and the new types of employment for S&E PhDs in the knowledge economy. Hence science doctorates' job mobility itself might not be an adequate indicator for academic knowledge flows to industry in the knowledge economy. Furthermore, the reluctance of many academic researchers to move to industry suggests that in order to foster knowledge transfer from academia, it may be more effective to encourage academics' temporary rather than permanent job mobility to industry. The paper suggests policy efforts could focus on encouraging academics to participate in research collaborations with industry with higher academic value and on supporting firms to take a more active role in seeking academic partners to help with more specific technical problems.

Keywords: science and engineering PhDs, knowledge flows, internal labour market, skills

1 Introduction

It is widely accepted that knowledge originated from university is a very important component of innovation and economic growth (e.g. Jaffe, 1989; Mansfield, 1991). Innovation scholars and policymakers seek to uncover factors that shape and encourage knowledge transfer from academia to industry. Among the various knowledge transfer channels, Bekkers and Freitas (2008) reported that doctoral graduates to industry is perceived to be highly important, and that the perceived importance of this knowledge transfer mechanism is higher than that of university spin-offs, academic-industry joint research, contract research by industry or industrial consultancy by academic staff. Surprisingly, however, little is known about how and the extent to which academic knowledge is transferred to industry through science doctorates' labour mobility.

We draw on an original survey designed to obtain retrospective data from graduates of a UK research-based university with 7-10 years job histories and analyse job mobility histories to understand the labour market of S&E PhDs. We gather information on the 'direction' of job mobility; that is, whether the job move is upward or lateral, intra- or inter-organisational, or within or across career types. These indicators are vital signals that characterise different labour market features. We use clustered sampling strategy and design-based non-parametric methods of analysis to maximise the potential for analysis at different levels (individual, job and job transition).

Our research shows striking results with important policy implications. We show that organisational careers are an important characteristic of the labour market of S&E PhDs, in particular for those who are in the conventional technical occupations. Furthermore, mobility and knowledge/skill development of science and engineering PhDs differ by career types. We find that those employed in academic/public research experience what we call 'dualist' labour market features, with internal labour markets but strong segmentation between core and peripheral workers. Those in technical positions in private sector manufacturing experience relatively more 'structured' internal labour market features. Finally, those employed outside the conventional technical occupations experience what we call 'hybrid' labour market features, with strong occupational labour market features. Those in academia/public research perceive skills from doctoral training as most useful; those in technical positions in private sector manufacturing perceive skills acquired from doctoral training as well as general skills as useful; those employed outside the conventional technical occupations value sector-specific and general skills. The differences in job mobility and knowledge and skill development of academic and public sector researchers and those of S&E PhDs in industry uncovers some of the most fundamental barriers for knowledge flows from academia to industry through science doctorates' job mobility. We suggest implications for innovation policy to encourage knowledge transfer from academia to industry.

The paper is organised as follows. Section 2 reviews the literature on careers of S&E PhDs, labour markets and their implications for knowledge transfer. Section 3 presents the methodology. Section 4 sets out the findings. Sections 5 and 6 present policy implications and a conclusion, respectively.

2 Literature review

2.1 Knowledge transfer and careers of S&E PhDs

Studies have long shown the importance of academic knowledge for innovation and economic growth (Jaffe, 1989; Mansfield, 1991). Knowledge transfer from university to industry has received considerable attention in the literature on academic-industry relations (Bekkers and Freitas, 2008; Cohen et al., 2002; D'Este and Patel, 2007; Meyer-Krahmer and Schmoch, 1998; Gregorio and Shane, 2003; Landry et al., 2007; Shane and Stuart, 2002) and academic entrepreneurship (Jain et al., 2009; Krabel and Mueller, 2009; Murray, 2004; Louis et al., 2001; Zucker et al., 2002). This literature has elucidated the characteristics of scientists or the motivations for scientists to engage in collaborations with industry (Ambos et al., 2008; Arvanitis et al., 2008; Lam, 2011; Link et al., 2007; Perkmann and Walsh, 2009; D'Este and Patel, 2007), the determinants of universities or laboratories' knowledge transfer activities (Gregorio and Shane, 2003; Harvey et al., 2002; Landry et al., 2007; Shane and Stuart, 2002), the agents of technology transfer (such as Technology Transfer Offices) (Ambos et al., 2008; Siegel et al., 2007) and the channels of knowledge and technology transfer (Bekkers and Freitas, 2008; Cohen et al., 2002; D'Este and Patel, 2007; Meyer-Krahmer and Schmoch, 1998). Within that literature, the mobility of scientists appears as a crucial mechanism of knowledge flows from university to industry. For instance, Bekkers and Freitas (2008) reported that labour (PhDs and academic staff) mobility is perceived to be very important when academic technological 'breakthroughs' are expected in such knowledge transfer activities. This is best illustrated in biotechnology. Zucker et al., (2002) pointed out that biotechnology firms with whom 'star' scientists collaborate are more likely to perform better (in terms of the number of patents and the intensity of patent citation). Murray (2004) also described how academic inventors bring not only their human capital but also their social capital such as networks with research laboratories and a wide range of connections with other scientists to firms. Edler et al., (2011) revealed that the most internationally mobile scientists are also the most active scientists who engage in knowledge transfer activities to industry in both home and the host countries. These insights indicate a positive association between academic scientists' mobility and knowledge flows to industry.

In fact, Bekkers and Freitas (2008) reported that among the various channels of academic knowledge transfer to industry, the perceived importance of doctoral graduates' labour mobility to industry is higher than the perceived importance of university spin-offs, academic-industry joint research, contract research by industry or industrial consultancy by academic staff. Moreover, S&E PhDs are particularly important as they are the only population that could potentially have careers across academia and industry. Surprisingly, how their career mobility is intertwined with academic knowledge transfer is little known. Most often, studies of careers of S&E PhDs derive from the concern regarding the increasingly fierce competition in securing permanent faculty positions because of the massification of higher education (since the mid 1990s, the number of doctoral awards in the UK has almost doubled). For instance, Mangematin (2000) explored the criteria for hiring PhD graduates in different sectors and incentives of PhD students. Gaughan and Robin (2004) investigated the factors affecting the propensity of securing a permanent academic position for PhDs in France and the US. Fox and Stephan (2001) revealed expectations and realities regarding employment among S&E PhDs in the US. Dany and Mangematin (2004) discussed employability of people with a doctoral degree in life sciences in France. Other studies explored the determinants of PhD career outcome (Robin and Cahuzac, 2003) and the value of doctoral research training (Enders, 2002).

Some studies explored S&E PhDs' contributions in industry. Stephan et al. (2007) examined the demand for the highly skilled in nanotechnology in the US. Stephan et al. (2004) also investigated how S&E PhDs may contribute to research activities in industry. However, these studies often assume that S&E PhDs, as long as they are employed in industry, will use the academic knowledge they produced or learned from doctoral training in their jobs. This assumption seems to have worked well in the past, when many S&E PhDs worked as R&D researchers in laboratories in large corporations in manufacturing such as chemical pharmaceutical or engineering industries. In these industries, there is a tradition of basic research and publication (Cohen and Levinthal, 1989; Stephan, 1996). In the modern knowledge economy, however, this assumption faces challenges. With the massification of higher education, including the proliferation of PhD awards, permanent faculty positions have been made very competitive and consequently, many S&E PhDs turn to work in industry. Also, due to structural changes including the decline of manufacturing, many of the S&E PhDs may not be working in R&D laboratories in manufacturing. For instance, according to the National Statistics workforce jobs by industry, the share of employment in manufacturing in the UK fell from 29% in 1978 to 8% in 2010. This raises the question of the extent to which S&E PhDs may no longer work as academic/public researchers or R&D researchers in manufacturing in industry and whether they might articulate academic knowledge differently. This also points out the need to explore knowledge and skill development of S&E PhDs in employment outside the conventional technical occupations.

The emerging employment for S&E PhDs in the knowledge economy is likely to be associated with professional services. Although Consoli and Elche-Hortelano (2010) showed that professional services that require higher educational qualifications also demand higher skills to be applied in jobs, the nature of those skills is still unclear, for example, in terms of the relevance of academic subject-specific knowledge. To open this black box, we build on Lee et al. (2010) who derived three career types of the S&E PhDs. The first includes employment in academic/public research and the second includes industrial scientist and engineer positions in manufacturing. These two career types are considered as the conventional S&E PhD jobs. A third career type covers all other jobs outside the conventional technical occupations. They showed that the perception of the value of knowledge and skill acquired from doctoral training differs among the three career types. However, knowledge acquired from doctoral training represents only part of knowledge and skill development of S&E PhDs in the labour market. An understanding of how knowledge that S&E PhDs produced in their doctoral training may be transferred to industry through their careers would inevitably involve a comparison of the development and flow of this specific type of knowledge and skills with other types of knowledge and skills. Furthermore, careers are structured within labour markets and labour market features of different carer types imply differences in knowledge and skill development. This suggests the potential of approaching knowledge and technology flows of S&E PhDs through the study of their labour market features. Studies on careers of scientists are normally the interest of labour economists. Studies on knowledge transfer activities of scientists are normally the interest of scholars in innovation studies. There are few inter-disciplinary efforts to link these two (de Grip et al., 2010). This paper intends to fill this literature gap. The following section reviews labour market models and outlines how these models may be associated with knowledge transfer activities through job mobility of S&E PhDs.

2.2 Labour market models

This study builds on labour market research by economists and sociologists to explore the particular features of the labour market of science and engineering PhDs. Doeringer and Piore (1971) introduced the distinction between primary and secondary labour markets. Piore (1971) stressed that the primary segment, associated with the internal labour market (ILM), “offers jobs which possess several of the following traits: high wages, good working conditions, employment stability and job security, equity and due process in the administration of work rules, and chances for advancement” (pp. 92). In the ILM, career ladders (and promotions) are structured within organisations and there is low turnover, long job tenure, organisation-specific skills and seniority based rewards (Doeringer and Piore, 1971; Kalleberg and Sørenson, 1979). The secondary segment, in contrast, involves less attractive jobs that offer “low wages, poor working conditions, considerable variability in employment, harsh and often arbitrary discipline, little opportunity to advance” (Doeringer and Piore, pp.92).

Although skilled workers are likely to experience ILM conditions in a primary segment, they may also be associated with the employment system of the occupational labour market (OLM). The OLM displays highly standardised formal education and training requirements, strong occupational associations and strong occupational identification (Marsden, 1986; Tolbert, 1996). The OLM is characterised by a high level of inter-organisational mobility, a low level of inter-occupational mobility and progressive enhancement of skills and responsibility (Althauser and Kalleberg, 1981). While job moves in the OLM do not always involve a pay rise, occupational credentials guarantee lateral mobility across organisations unlike ILMs, where inter-firm mobility can in principle lead to a downward move. Indeed, the two ideal types of labour markets associated with skilled workers differ in the degree of organisation-specificity or ‘portability’ of knowledge and skill development (Estevez-Abe et al., 2001; Eyraud et al., 1990). ILMs feature a high degree of organisation-specificity skills, while OLMs feature knowledge/skill development that is not specific to a given organisation and can be easily circulated and is valued by other employers of the occupation. OLMs are therefore associated with a higher level of inter-organisational mobility within an occupational group and a low level of inter-occupational mobility.

However, the traditional distinction between organisation-specific and general skills in labour markets (Eyraud et al., 1990), which is used to differentiate the ILMs and the OLMs, is far from adequate to grasp the peculiar nature of S&E PhDs’ knowledge and skill development (Mangematin, 2001; Pelz and Andrews 1966). For instance, doctoral training can neither be equated to easily portable skills to different kinds of employment contexts nor regarded as organisation-specific skills. The role that doctoral training plays in the labour market of S&E PhDs remains unclear. Similarly, skills that facilitate inter-organisational job mobility could range from knowledge that is portable to any organisation within an industry or sector to knowledge that is portable to any organisation in any industry or sector. The concept of knowledge that might be specific to an industry or a sector is in line with the discussion of sector-specific knowledge that is well documented in the innovation literature, but has rarely been discussed in the labour market literature. Indeed, the innovation literature argues that sectors differ in knowledge base and innovation patterns; knowledge is not general-purpose or easily transmitted and reproduced, but differentiated and localised, tacit and cumulative over time, and appropriable by specific firms in a sector

(Nelson and Winter, 1977; Pavitt, 1984). Estevez-Abe et al. (2001) define sector-specific skills as skills that are specific to and raise productivity in a specific sector but not in others. Sector-specific knowledge is then expected to be more general and portable across organisations in a sector but it is more specific when compared to other sectors. Knowledge that is portable to any organisation in any industry or sector might be simply labelled as general skills. Following this line of argument, sector-specific skills and general skills could all provide potential for inter-organisational mobility within an occupation. Therefore, we suggest that S&E PhD knowledge and skills comprise not only knowledge and skills acquired through doctoral training, but also knowledge and skills that are specific and can only be valued within a particular organisation or a sector, as well as knowledge and skills that are general and can be used in any context.

An additional challenge is to define the concept of occupation for the labour market of S&E PhDs. Occupational groups have been defined in the literature in different ways - according to types of work (physical and non-physical) (Dawis et al., 1979), socio-economic status (such as blue-collar and white collar) (Herr and Cramer, 1984), or a further grouping of occupational titles (LFS, 2009). In particular, Cheng and Kalleberg (1996) suggested that an "occupation refers to technical work activities that are transferred among employers and to skills that are transportable from firm to firm" (pp.1238). This definition indicates that technical activities and skills are expected to be relatively similar within one occupation but distinctly different in other occupations. That is to say, this definition uses knowledge and skills to distinguish between different occupations.

A further criticism of the ILM and OLM ideal-type labour market structures may be relevant to an understanding of the labour markets of S&E PhDs. Wider economic and technological changes mean skilled workers may experience segmented career paths. Increased competition, uncertainty and technological change in modern deregulated industrial economies have led organisations in countries such as the UK and the USA to adopt a 'flexible firm' strategy that involves both functional flexibility (the ability of employers to redeploy employees quickly and smoothly between activities and tasks) and numerical flexibility (the ability of organisations to adjust the size of their workforce in response to the fluctuation in demand by using workers who are not in their regular permanent full-time employment) (Atkinson, 1984; Kalleberg, 2003). In order to benefit from these two kinds of flexibility, the firm may polarise the workforce into 'core' and 'peripheral' groups. Workers in the core group are most likely to be full-time permanent employees; they participate in organisations' key activities and are provided with favourable career prospects. However, increasingly, their employment security comes at the cost of accepting functional flexibility, which requires multi-skilling, career changes and merit-based pay. Nevertheless, core workers are insulated from medium-term market fluctuations and at most expect changes in tasks and responsibilities. In contrast, the peripheral group comprises part-time, temporary and contract workers who experience job insecurity and limited progression. This group of workers is directly exposed to market fluctuations. An important implication of this model is that highly skilled workers may not be immune from becoming peripheral workers - typical examples including consultants and independent professionals (Kalleberg, 2003).

These contributions on ILM and OLM and criticisms suggesting alternative features of labour markets provide a basis for an understanding of the labour market of S&E PhDs. We build on these to develop below a detailed analysis of the specific features of the labour market of S&E PhDs and outline the implications of knowledge transfer through S&E PhDs' careers.

3 Methodology

We explore the labour market of science and engineering PhDs through a survey of graduates from a UK research-based university, the University of Manchester.[1] Our strategy was to adopt a single university setting to avoid the effects and complexities caused by different universities and regions. Furthermore, the University of Manchester is the largest single-site university in the UK and has renowned and well-developed engineering and physical science departments. This provides a reasonable size sample. Moreover, it is a member of the UK Russell Group, which represents the top 20 leading universities in the UK. Its leading position means that it offers attractive doctoral training for PhDs seeking either an academic career or a degree respected by industrial employers. We also adopt the strategy of selecting home (UK and other EU) PhD students graduated from specific years to minimise culture and cohort effects.

The population sampled for the survey includes all the home PhD students that graduated between 1998 and 2001 from the science and engineering disciplines from the University and all jobs they have had since doctoral training. The sampling frame comprises 512 PhDs with UK addresses and 84 names with other EU addresses at the individual level. The sampling strategy is a single stage clustered sampling (individuals as primary sampling units and jobs as secondary sampling units), and as all PhDs in the sampling frame have the same selection probability and all jobs[2] from individuals have the same selection probability, the sample is self-weighted. Such a sampling strategy allows jobs to be clustered into individuals. It is assumed that individuals are independent from each other, whereas jobs are correlated with the individuals to whom they belong.

The survey collects retrospective employment history (at the individual and job level). It covers 7-10 years employment history in order both to allow for changes in jobs and to minimise non-responses caused by too long a period. The questionnaire asks PhDs details of their current and past jobs (including dates, sector, title, job task, whether the job is permanent, full-time, whether the job is the result of a promotion from the previous job and whether the job involves a change of employer). We designed a questionnaire that asks all the relevant questions with a layout of four A4 pages printed double sided on an A3 page.

One of the main considerations of our research design was to overcome difficulties in accessing personal information due to the UK 1998 Data Protection Act. Thus, the survey was conducted by post through the Alumni Office to preserve confidentiality. The survey was posted between April and July 2008. The first wave of the survey resulted in 82 responses in four weeks. E-mail reminders were sent to encourage responses. After the deadline, 20 more respondents returned the survey questionnaires. A total of 91 UK and 11 other EU responses were obtained. There were 38 UK and 7 other EU undelivered returned questionnaires. The overall response rate is 18.5% at individual level (19.2% for UK addresses and 15.3% for other EU addresses). A total of 102 individuals and 282 jobs are obtained. As the sample is self-weighted, bias could come mainly from non-responses. Non-response bias has been assessed and no significant bias is found.[3]

Three types of units of analysis are used: the individual, the job and the job transition. A job transition indicates a change from one job to another and is mainly used to assess whether it involves a change in employer or in occupation, whether it is associated with a promotion and the type of knowledge and skills that are perceived as the most useful in the transition. We limited our study to respondents with UK addresses in order to eliminate international differences in labour market features. We also used respondents previously or currently in professional jobs only. In this smaller sample, 90 responses, 239 jobs and 161 job transitions are used for analysis (Table 1).

Insert Table 1

When the individual is used as the unit of analysis, the analysis is based on un-weighted descriptive data analysis. When the job or job transition is used as the unit of analysis, the analysing approach adopted is design-based (Cochran, 1977; Lehtonen and Pahkinen, 2003; Skinner et al. 1989). The latter takes into account the complexity of sampling design and the existence of intra-cluster correlation and uses non-parametric variance estimators. Such non-parametric variance estimators are generally unbiased and consistent but result in higher variances and inefficiency. The design-based approach estimates marginal effects of explanatory variables and is particularly suitable for research with an exploratory purpose. This approach is different from the model-based approach, which seeks to establish precise models, to estimate independent effects and to have predictive power.

As the sampling design is self-weighted and although it appears that there is no significant non-response bias, a post-stratification adjustment is applied to weight the gender-discipline-year of graduation-location subgroups so that they will be identical to those in the population. Methods of analysis comprise design-based descriptive data analysis such as the design-based chi-square tests for independence. The analysing tool is STATA Release 10.1. For survey data analysis, by default, the STATA svy command uses the linearisation method based on a first-order Taylor series linear approximation for covariance matrix estimation and the pseudolikelihood estimation to fit the model.

Three key indicators are explored: organisational mobility, occupational mobility, and knowledge and skill development. The use of these indicators is intended to differentiate between the ILM and the OLM, the two labour market models that are closely associated with the highly skilled (Table 2). These indicators are drawn from the literature on labour market theories reviewed above, which suggested that the ILM is associated with intra-organisational upward mobility and the OLM with inter-organisational mobility that is either upward or lateral (not involving promotion). It is also suggested that the OLM is associated with intra-occupational mobility. While in the ILM there is high specificity of knowledge and skill development, in the OLM there is low specificity of knowledge and skill development. Furthermore, we determine core and peripheral workers based on whether they have been offered permanent or fixed-term contracts.

Insert Table 2

We asked respondents to indicate for each of their jobs, whether they were promoted from the previous job and whether the job transitions involved a change in employer. This resulted in four possible types of mobility: 1) intra-organisational upward mobility (38% of the survey sample), 2) inter-organisational upward mobility (22%), 3) intra-organisational non-promotion mobility (9%), and 4) inter-organisational non-promotion mobility (31%).

As argued above, since knowledge and skill development can be used to distinguish between occupations, we define the S&E career types proposed by Lee et al. (2010) (i.e. academic/public research, technical positions in the private sector manufacturing and employment outside the conventional occupations) as three different occupational groups, because the perceived usefulness of knowledge is relatively similar within a career type but distinctively different from the others. Hence, types of occupational mobility are constructed based on information given by respondents on the career types. For each job transition, the type of occupational mobility can be defined by the career type the previous job was in and by the career type the subsequent job belongs to after the job move. Therefore, nine types of mobility are possible (Appendix Table 1). However, the distribution of types of job transitions shows that only five types of mobility are significant in practice, as each of the remaining four types accounts for no more than 2% of the surveyed job transitions. Out of these five, three involve mobility within career types: 1) remaining a researcher in academic/public research (19%), 2) remaining an industrial scientist or engineer in manufacturing (11%) and, by far the most common type, 3) remaining employed outside the conventional technical occupations (47%). Two involve mobility across career types: 1) from academic/public research to employment outside the conventional technical occupations (8%) and 2) from industrial scientist or engineer in manufacturing to employment outside the conventional technical occupations (9%).

With regards to the types of knowledge and skills that are relatively more valuable for each job transition, we asked respondents to select one skill from the following four: 1) skills acquired from the PhD training, 2) organisation-specific skills acquired from the previous position, 3) sector-specific skills acquired from the previous position, and 4) general skills. The assessment of what skills from a previous job were useful in the subsequent job makes it possible to evaluate skill development and knowledge flows in the labour market. From all job transitions, the analysis indicates that 27% of respondent rated "skills acquired from PhD" as the most useful in the job transition, 18% of respondents rated "organisation-specific skills acquired from previous position", 27% rated "sector-specific skills acquired from previous position" and 28% rated "general skills".

4 Findings

4.1 Different labour market features by career types

Descriptive data analysis based on individual respondents shows that, on average, 69% of the survey respondents have worked for only one or two employers 7-10 years after graduation. This shows that organisational life is still important for the early- to middle-stage careers of the survey respondents. We explored further job mobility and career types, using the following definitions to describe career trajectories of our respondents within or across career types. We defined as 'stayers' the respondents who have experienced a pattern of intra- and inter-organisational job mobility that is confined to a single career type (e.g., confined to academic/public research). We defined as 'movers' the respondents who have experienced at least one job move across career types. That is, movers have encountered inter-occupational job mobility. The two groups are mutually exclusive. We pointed out above that only two types of inter-occupational job transitions are significant: transitions out of academic/public research and transitions out of technical positions in private sector manufacturing. Furthermore, the direction of job transitions is towards employment outside the conventional technical occupations. This indicates that once a S&E PhD moves into employment outside the conventional occupations, he or she remains in this career type as the propensity to move back to academic/public research or industrial R&D labs in manufacturing is rare. Although movers also have job transitions within the conventional technical occupations before they move out of these career types, we are interested in movers' three main types of job transitions: transitions out of academic/public research, transitions out of technical positions in manufacturing and transitions within employment outside the conventional technical occupations. Based on design-based descriptive data analysis using job transitions as analysing units, stayers and movers' organisational mobility by career types/occupational mobility is shown in Table 3. Stayers and movers' knowledge and skill development by career types is shown in Table 4.

Insert Tables 3 and 4

These results drive us to derive three types of labour market features of the labour market of S&E PhDs. We discuss below each of these different labour market features.

4.2 'Dualist' labour market features for those in academic/public research

Those who remained in academic/public research throughout the survey period experienced a strong likelihood of upward job mobility within their existing organisations (60% of the sample, Table 3). They were also far more likely to perceive skills acquired from doctoral training, which is considered more specific and less portable, to be the most useful type of knowledge in a job transition (72%, Table 4). These two indicators point to ILM-type labour market features experienced by those who have a career in academic/public research.

However, these ILM features are coupled with evidence of segmentation. More than two thirds of those who began their career in academic/public research were offered jobs on a fixed-term basis. By comparison, the number of fixed-term positions offered in the other two career types is almost negligible. Even after 7-10 years after graduation, more than one third of respondents in academic/public research remain in fixed-term positions. The high use of fixed-term contracts may indicate that many universities and public research organisations are segmenting their labour force into 'core' and 'peripheral' groups in order to adjust to changing market conditions (Atkinson, 1984). Core workers, such as faculty members, may be organised according to typical ILM arrangements, while peripheral workers, such as fixed-term researchers, may be organised according to more competitive and less secure employment features (Camuffo, 2002). S&E PhDs in this career type can therefore be described as experiencing 'dualist' labour market features, with segmentation between 'core' and 'peripheral' workers.

4.3 'Structured' labour market features for those in technical positions in private sector manufacturing

For those who started their careers as industrial scientists in manufacturing, 7-10 years after graduation, only half remain in this career type. Although this seems to be the least popular career type for the respondents - a finding that differs from the French case (Mangematin, 2000) - career progression in this career type appears to be rather stable and positive, showing ILM features. That is, if graduates continue to stay in this career type, they seem to enjoy careers with promotions within existing organisations (67% of the sample, Table 3). Our findings are very much in line with Marsden (2010), as industrial scientists and engineers in manufacturing seem to be still situated in a very 'structured' labour market.

Although skills acquired from doctoral training show considerable importance for stayers' promotion (37%) in this career type, such high propensity of intra-organisational upward job mobility seem to be accompanied with use and development of general skills (37%) (Table 4). This might be explained by awareness of the possibility of having to switch to a career of dedicated managers (Allen and Katz, 1992). Consequently, the acquisition of managerial skills may have become a part of the knowledge and skill development of industrial scientists, even if they remain in the technical track. A detailed case-by-case investigation (due to limited cases in this category) reveals that only about half of the movers out of this career type become dedicated managers internally or externally to their existing organisations, while the other half not only switch their career track from manufacturing to services, but also change employers, although remaining in the technical track. This uncovers another potential career track for industrial scientists in manufacturing other than becoming dedicated managers. However the investigation also shows that the change of technical track from manufacturing to services often involves lateral move.

4.4 'Hybrid' labour market features for those employed outside the conventional technical occupations

Once a S&E PhD is employed outside the conventional technical occupations, the propensity to switch back to the conventional technical occupations is very low. Therefore, job mobility of workers employed outside the conventional technical occupations is highly restricted to this career type. For those who have always been in this career type, the propensity for inter-organisational mobility, a key feature of the OLM, is relatively high at 54% (Table 3). Moreover, close to three quarters of these stayers value knowledge and skills that are more general and portable, i.e. sector-specific skills (40%) and general skills (31%) (Table 4).

There are also movers who move into this career type from academic/public research or technical positions in private sector manufacturing. We showed above that movers' job transitions out of their original career types in the conventional technical occupations show a considerable deviation from the ILM-like labour market features shared by stayers in these career types. This feature appears to be limited to these specific job transitions only. Once movers move into employment outside the conventional technical occupations, their organisational mobility and knowledge and career development show no difference from those of stayers who have always been in this career type.[4] That is to say, PhDs' job transition pattern and knowledge and skill development in this career type are not affected by their previous working experience in different career types (i.e. whether they come from the conventional technical occupations or whether they have always been outside the conventional occupations).

Although showing high level of inter-organisational job mobility, PhDs in this career type are on average still more likely to have promotions internally within organisations (stayers: 37%; movers: 32%) than externally (stayers: 29%; movers: 22%) (Table 3); hence, in this career type, organisational career life remains important. In order to understand better why this career type shows such a job mobility pattern, a case-by-case investigation is useful. This indicates that jobs in this career type are largely made up of dedicated managers (29%), consultants and many other technical professionals in services (49%). Dedicated managers comprise those who are promoted from technical positions in manufacturing (industrial scientist-turned-dedicated managers) and those who have always been in services. Industrial scientist-turned-dedicated managers (originally from technical positions in manufacturing) are equally likely to be promoted internally or externally to organisations. Dedicated managers in services are twice as likely to be promoted externally than internally. On the other hand, job mobility for technical positions in the private sector services or consultants, which account for 49% of the jobs in this career type, is either intra-organisational upward or inter-organisational lateral (around 1:1). All these groups, however, appear to have a more prominent inter-organisational job mobility feature. Organisational life remains important for technical professionals in services, but not so much for dedicated managers in services. Based on these results, we can conclude that the career behaviour of those employed outside the conventional technical occupations shows stronger OLM features.

5 Implications for innovation policy

By rendering the career type of employment outside the conventional technical occupations explicit, we have been able to unpack the interrelationships between S&E PhDs' job mobility and knowledge and skill development. The distinctive labour market features for the three career types suggest a number of implications for policymaking, education and management of S&E PhDs. For universities, although they benefit from research input from doctoral students and fixed-term researchers, they might need to consider how to provide career guidance to them. Individuals, including doctoral students and fixed-term researchers, could pay more attention to different career paths in different types of employment and their corresponding work-related competences.

However the implications of the research findings go beyond universities' human resource management and S&E PhDs' management of their careers. It appears that there are barriers for knowledge flows from academia to industry through S&E PhDs' job mobility. These barriers and implications are outlined below.

5.1 Barriers to knowledge flows from gap in the knowledge base

Our findings indicated that knowledge and skills acquired from S&E doctoral training largely stay and are circulated within organisations and within the conventional technical occupations. If the conventional technical occupations in industry (i.e. technical positions in private sector manufacturing) had been the major private sector employment destination for S&E PhDs, we would have been able to conclude without doubt that a large amount of knowledge acquired from S&E doctoral training, even subject-specific knowledge, is transferred from academia to industry through individuals' job mobility. However, this is not the case, because technical positions in manufacturing represent only a minority of S&E PhD's employment (Lee et al., 2010). On the one hand, academic knowledge seems to flow naturally to private sector manufacturing through technical tasks conducted by S&E PhDs. On the other hand, however, the majority of the surveyed S&E PhDs eventually find employment outside the conventional technical occupations and the extent to which they perceive knowledge from doctoral training to be useful is limited. This suggests that there is a wide gap in knowledge base between academia and employment outside the conventional S&E PhD jobs. Indeed, in the knowledge economy, therefore, job mobility of S&E PhDs to industry may not be an adequate indicator for the transfer or flow of academic knowledge to industry.

In the UK, there have been explicit policies designed to encourage direct knowledge flows from academia to industry (Howells et al., 1998). One of the most relevant is the EPSRC (Engineering and Physical Sciences Research Council) EngD (Engineering Doctorate) Scheme. This has been launched to recruit research engineers since 1992. The scheme requires doctoral students to spend 75% of the time working directly in industry under the supervision of their industrial supervisors and 25% of the time at university attending taught technical specialist and management courses.[5] The outcome is yet to be assessed. It is unclear how academics in engineering and physical sciences could collaborate with professional services and the extent to which the knowledge gap could be bridged. We urge that policies that encourage the diffusion of academic knowledge to industry through S&E PhDs' job mobility should pay attention not only to the PhD scientists and engineers' job mobility to industry, but also to how to bridge the gap in knowledge base between academia and employment outside the conventional S&E occupations (e.g. knowledge-intensive business services jobs). This specific aspect requires further research.

5.2 Barriers to knowledge flows from academic scientists' motivation

The study showed very specific labour market features for those in academic/public research, including the hazard of remaining at the bottom of the academic career ladder, with transitions from fixed-term research to the private sector often meaning a completely new start in industry (lateral move). Despite these challenges, many S&E PhDs are willing to attempt a career in academic/public research. Indeed, 39% of the survey respondents had academic/public research positions as their first jobs. This implies that it would be over-simplistic to approach research on careers of S&E PhDs by only considering objective incentives and measures such as promotions. An example is the account given by a post-doctoral researcher in mechanical engineering at one of the top UK research-based universities in our preliminarily interviews:

"I have been doing post-doctoral research since I got my PhD [for six years]. Many of my (fellow PhDs) are working in engineering consultancy or BAE Systems. Here, at least 4 fellow PhDs I know went to banking. They are modelling the stock market using the same methods we are using here. The money is very good in banking but for me that kind of job is boring. I have never considered going there. …The only choice for my career is doing research. I knew that permanent academic positions are difficult to get from the beginning, and now my salary is [low], but I choose to pursue an academic career because of my passion for research. "

This is in line with the contribution of career theorists who stress that the concept of careers can not be reduced only to the prospects of upward progression or material rewards (Hall, 2002; Mirvis and Hall, 1996). This also means that it is important to understand why some academic researchers are reluctant to engage in job mobility to industry (in particular permanent job mobility), even given high material incentives. Policies that focus mainly on providing financial or material incentives to foster mobility from academia to industry would probably be ineffective. For instance, despite policy efforts, academic-turned-entrepreneurs who capitalise their research remain rare (D'Este and Patel, 2007). Even among university start-ups in life sciences, Meyer (2003) showed that many academics involved in the setting up of new firms are more like entrepreneurial academics (who establish firms but remain working in universities), rather than academic entrepreneurs (who become dedicated businessmen). In a case study, Murray (2004) also pointed out that none of the ‘star’ academic scientists in that study who capitalise their inventions move to the firms on a full time basis. This may mean that it may be more effective to develop policies that encourage academics’ temporary (rather than permanent) mobility across the academia-industry boundary.

Also, this suggests the potential of university-industry collaborative research to benefit both the scientific community and industry through knowledge flows. In a study of various types of university-industry collaborative research, Perkmann and Walsh (2009) found that collaborative research projects that focus on providing firm-specific solutions for firms’ R&D, manufacturing or other operations are often initiated by firms and result in few academic publications. On the other hand, collaborative research projects that aim at exploring high-risk concepts or generating knowledge on subject areas but are only of broad interest to firms are most likely to be initiated by academics and result in high academic value and publications. The finding that academics would be more passive in pursuing research that is directly tied to industry would not come as a surprise given the career behaviour of academics from research-based universities. This suggests implications for policies aiming at fostering knowledge flows from academia to industry through academics’ mobility. First, policies could focus on encouraging firms to take an active role in seeking collaborations with academics in research that is directly tied to firms’ industrial applications. It would be ineffective to expect academics, especially those who are in research-based universities, to take an active role in this type of collaboration. Second, for academia, policies may focus on encouraging academic researchers to form collaborative research that may help them to test their ideas in the real world and generate knowledge with academic value. This approach to encourage academics to work with industry is more likely to be effective, as many academics seem to have been actively pursuing this.

6 Conclusions

This paper investigated the histories of job mobility of individuals to explore the labour market features of S&E PhDs. We found that job mobility and knowledge and skill development differ by career types. Three distinctive types of labour market features are identified. Those employed in academic/public research face ‘dualist’ labour market features, showing a sharp contract between core and peripheral workers. Consistent with labour market theories, those who have built careers in this career type value knowledge from doctoral training, a less portable type of knowledge, and largely enjoy promotion within existing organisations. However, this career type also exhibits a large amount of fixed-term contract researchers who move out of the career type without promotion when not succeeding in obtaining permanent positions. Those in technical positions in private sector manufacturing experience ‘structured’ internal labour market features. PhDs in this career type draw knowledge from their doctoral training and develop general skills. This career type seems to have labour market features the explanation of which is relatively straightforward: industrial scientists or engineers in manufacturing largely experience promotions internal to their organisations until they become dedicated managers or decide (voluntarily or involuntarily) to switch career track to other sectors such as services. Those employed outside the conventional technical occupations face ‘hybrid’ labour market features. Here the more ‘portable’ knowledge - sector-specific knowledge and general skills - is important. PhDs in this career type are more likely to move around organisations and this career type hence shows stronger occupational labour market features.

Our findings thus have implications for policies fostering knowledge flows from academia to industry through S&E PhDs’ job mobility. Two types of barriers in this type of knowledge transfer are identified. First, we have suggested that an important impact of the knowledge economy on careers of S&E PhDs is that many are in employment outside the conventional technical occupations (i.e. not as academic/public sector researchers or researchers in R&D labs in manufacturing). We have also pointed out that there are barriers for academic knowledge to flow to this career type through S&E PhDs job mobility. The barriers do not seem to be associated with actual job mobility of S&E PhDs, as the majority of them eventually find employment in this sector. Instead, the barriers are more likely to be the result of a gap in knowledge base between the conventional jobs and those outside the conventional S&E PhDs’ occupations, because knowledge acquired from doctoral training is not perceived to be very useful in the latter. Further research to explore this is needed. Second, knowledge transfer requires scientists’ willingness to move. This research revealed that even fixed-term academic researchers are reluctant to move to industry. This suggests that policies that encourage cross border job mobility from academia to industry may be more effective if they focused on temporary rather than permanent mobility. Policies that encourage university-industry collaborations, including entrepreneurial activities, seem to be in the right direction. Regarding this, we have further suggested that within university-industry collaborations, it is more likely that academics will be more responsive to policies that encourage collaborative research that generate knowledge with academic value. In contrast, for collaborative projects that are highly industrial relevant and aimed at solving firm-specific technical problems, it would be more effective to focus on providing channels for firms, rather than academics, to actively seek academic research partners.

We acknowledge some limitations of this study. We focus on S&E PhDs from the University of Manchester with 7-10 years of employment history in the labour market. The inferences do not go beyond the survey population. There is scope to explore further career behaviour of PhD scientists and engineers from non-research-based universities. Nevertheless, overall, we believe that our research sheds light on the understanding of career behaviour of S&E PhDs, and provide valuable policy implications for fostering academic knowledge flows to industry through scientists and engineers’ job mobility.

References

1. Allen, T. J. and Katz, R., 1992. Age, education and the technical ladder. IEEE Transactions on Engineering Management, 39, 237-245.
2. Althauser, R. P. and Kalleberg, A. L., 1981. Firms, occupations and the structure of labour markets: a conceptual analysis. In: Berg, I. (Ed), Sociological Perspectives on Labour Markets. New York: Academic Press.
3. Ambos, T., Mäkelä, K., Brikinshaw, J. and D'Este, P., 2008. When does university research get commercialized? Creating ambidexterity in research institutions. Journal of Management Studies 45(8), 1424-1447.
4. Arvanitis, S., Kubli, U. and Woerter, M., 2008. University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprise. Research Policy 37, 1865-1883.
5. Atkinson, J., 1984. Manpower strategies for flexible organisations. Personnel Management, August, 24-31.
6. Bekkers, R. and Freitas, I. M. B., 2008. Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? Research Policy 37, 1837-1853.
7. Camuffo, A., 2002. The changing nature of internal labour markets. Journal of Management and Governance 6, 281-294.
8. Cheng, M. M. and Kalleberg, A. L., 1996. Labour market structures in Japan: an analysis of organisational and occupational mobility patterns. Social Forces 74(4), 1235-1260.
9. Cochran, W. G., 1977. Sampling Techniques (3rd ed.). Wiley, New York.
10. Cohen, W. M. and Levinthal, D. A., 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99(397), 569-596.
11. Cohen, W. M., Nelson, R. R. and Walsh, J. P., 2002. Links and impacts: the influence of public research on industrial R&D. Management Science 48 (1), 1-23.
12. Consoli, D. and Elche-Hortelano, D., 2010. Variety in the knowledge base of Knowledge Intensive Business Services. Research Policy 39, 1303-1310.
13. D'Este, P. and Patel, P., 2007. University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? Research Policy 36, 1295-1313.
14. Dany, F. and Mangematin, V., 2004. Beyond the dualism between lifelong employment and job insecurity: some new career promises for young scientists. Higher Education Policy 17, 201-219.
15. Dawis, R. V., Lofquist, L. H., Henly, G. A. and Rounds, J. B., Jr., 1979. Minnesota Occupational Classification System II (MOCS II). Vocational Psychology Research Work Adjustment Report, Minneapolis.
16. de Grip, A., Hall., B. H. and Smits, W., 2010. Empirical studies of employment and performance of scientists and engineers. Economics of Innovation and New Technology 19(5), 387-391.
17. Doeringer, P. B. and Piore, M. J., 1971. Internal Labour Markets and Manpower Analysis. DC Heath, Lexington.
18. Edler, J., Fier, H. and Grimpe, C., 2011. International scientist mobility and the locus of knowledge and technology transfer. Research Policy 40, 791-805.
19. Enders, J., 2002. Serving many masters: the PhD on the labour market, the everlasting need of inequality, and the premature death of Humboldt. Higher Education 44, 493-517.
20. Estevez-Abe M., Iversen, T. and Soskice, D., 2001. Social protection and the formation of skills: a reinterpretation of the welfare State. In: Hall, P. A. and Soskice, D. (Eds), Varieties of Capitalism. Oxford University Press, Oxford.
21. Eyraud, F., Marsden, D. and Silvestre, J. J., 1990. Occupational and internal labour markets in Britain and France. International Labour Review 129(4), 501-517.

22. Fox, M. F. and Stephan, P. E., 2001. Careers of young scientists: preferences, prospects and realities by gender and field. Social Studies of Science 31(1), 109-122.

23. Gaughan, M. and Robin, S., 2004. National science training policy and early scientific careers in France and the United States. Research Policy 33, 569-581.

24. Gregorio, D. D. and Shane, S., 2003. Why do some universities generate more start-ups than others? Research Policy 32, 209-227.

25. Hall, D. T., 2002. Protean Career in and out of Organizations. Sage, Thousand Oaks, CA.

26. Harvey, J., Pettigrew, A. and Ferlie, E., 2002. The determinants of research group performance: towards Mode 2? Journal of Management Studies 39(6), 747-774.

27. Herr, E. L. and Cramer, S. H., 1984. Career Guidance and Counselling through the Lifespan: Systematic Approaches. HarperCollins, New York.

28. Howells, J., Nedeva, M. and Georghiou, L., 1998. Industry-Academic Links in the UK. PREST, University of Manchester, Manchester.

29. Jaffe, A., 1989. The real effects of academic research. American Economic Review 97(5), 957-970.

30. Jain, S., George, G. and Maltarich, M., 2009. Academics or entrepreneurs? Investigating role identity modification of university scientists involved in commercialization activity. Research Policy 38, 922-935.

31. Kalleberg, A. L. and Sørenson, A. B., 1979. The sociology of labour markets. Annual Review of Sociology 5, 351-379.

32. Kalleberg, A. L., 2003. Flexible firms and labour market segmentation. Work and Occupations 30. 154-175.

33. Krabel S. and Mueller, P., 2009. What drive scientists to start their own company? An empirical investigation of Max Plank Society scientists. Research Policy 38, 947-956.

34. Lam, A., 2011. What motivate academic scientists to engage in research commercialisation: 'Gold', 'ribbon' or 'puzzle'? Research Policy 40, 1354-1368.

35. Landry, R., Amara, N. and Ouimet, M., 2007. Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineers. Journal of Technology Transfer 32, 561-592.

36. Larédo, P., 2007. Revisiting the third mission of universities: Toward a renewed categorization of university activities? Higher Education Policy 20, 441-456.

37. Lee, H. -F., Miozzo, M. and Laredo, P., 2010. Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university. Research Policy 39(7), 869-881.

38. Lehtonen, R. and Pahkinen, E. J., 2003. Practical Methods for Design and Analysis of Complex Surveys. John Wiley & Sons, Chichester.

39. LFS User Guide Volume 5, 2009. http://www.statistics.gov.uk/downloads/theme_labour/ Vol5_ 2009.pdf (accessed on 14 January 2011)

40. Link, A. N., Siegel, D. S. and Bozeman, B., 2007. An empirical analysis of the propensity of academics to engage in formal university technology transfer. Industrial & Corporate Change 16(4), 641-655.

41. Louis, K. A., Jones, L. M., Anderson, M. S., Blumenthal, D. and Campbell, E. G., 2001. Entrepreneurship, secrecy and productivity: A comparison of clinical and non-clinical life science faculty. Journal of Technology Transfer 26 (3), 233-245.

42. Mangematin, V., 2000. PhD job market: professional trajectories and incentives during the PhD. Research Policy 29, 741-756.

43. Mangematin, V., 2001. Individual careers and collective research: is there a paradox? International Journal of Technology Management 22(7/8), 670-675.

44. Mansfield, E., 1991. Academic research and industrial innovation. Research Policy 20(1), 1-12.

45. Marsden, D., 1986. The End of Economic Man? John Spiers, Brighton.

46. Marsden, D., 2010. The growth of extended ‘entry tournaments’ and the decline of institutionalised occupational labour markets in Britain. CEP Discussion Paper No 989, LSE.

47. Meyer, M., 2003. Academic entrepreneurs or entrepreneurial academics? Research-based ventures and public support mechanism. R&D Management 33(2), 107-115.

48. Meyer-Krahmer, F. and Schmoch, U., 1998. Science-based technologies: university-industry interactions in four fields. Research Policy 27, 835-851.

49. Mirvis, P. H. and Hall, D. T., 1996. Psychological Success and the Boundaryless Career, In: Arthur, M. B and Rousseau, D. M. (Eds), The Boundaryless Career. Oxford University Press, New York.

50. Murray, F., 2004. The role of academic inventors in entrepreneurial firms: sharing the laboratory life. Research Policy 33, 643-659.

51. Nelson, R. R. and Winter, S. G., 1977. In search of a useful theory of innovation. Research Policy 5, 36-76.

52. Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343-373.

53. Pelz, D. C. and Andrews, F. M., 1966. Scientists in Organizations. John Wiley and Sons, New York.

54. Perkmann, M. and Walsh, K., 2009. The two faces of collaboration: impacts of university-industry relations on public research. Industrial and Corporate Change 18(6). 1033-1065.

55. Piore, M. J., 1971. The dual labour market. In Gordon, D. (Ed), Problems in Political Economy. D. C Health and Co., Lexington, MA.

56. Robin, S. and Cahuzac, E., 2003. Knocking on academia’s doors: an inquiry into the early careers of doctors in life science. Labour 17(1), 1-23.

57. Shane, S. and Stuart, T., 2002. Organisational endowments and the performance of university start-ups. Management Science 48 (1), 154-170.

58. Siegel, D. S., Veugelers, R. and Wright, M., 2007. Technology transfer offices and commercialization of university intellectual property: performance and policy implications. Oxford Review of Economic Policy 23(4), 640-660.

59. Skinner, C. J., Holt, D. and Smith, T. M. F., 1989. Analysis of Complex Surveys. Wiley, New York.

60. Stephan, P. A., 1996. The economics of science. Journal of Economic Literature 34, 1199-1235.

61. Stephan, P. E., Gurmu, S., Sumell, A. J. and Black, G., 2007. Who’s patenting in the university? Evidence from the survey of doctorate recipients. Economics of Innovation and New Technology 16, 71-99.

62. Stephan, P. E., Sumell, A. J., Black, G. C. and Adams, J. D., 2004. Doctoral education and economic development: the flow of new Ph.D.s to industry. Economic Development Quarterly 18, 151-167.

63. Tolbert, P. S., 1996. Occupations, organizations, and boundaryless careers. In Arthur, M. B and Rousseau, D. M. (Eds), The Boundaryless Career. Oxford University Press, New York.

64. Zucker, L. G., Darby, M. R. and Torero, M., 2002. Labor mobility from academe to commerce. Journal of Labor Economics 20(3), 629-660.

Table 1: Demographic characteristics of respondents,

Year of graduation		Gender		Whether currently in employment	
1998	21%	Male	72%	In paid employment	90%
1999	25%	Female	28%	Running own company/freelancing	3%
2000	29%			Unemployed/looking after family	7%
2001	25%				

Note: UK address only. N=90

Table 2: Indicators of the ILM and OLM

	Organisational mobility				Occupational mobility		Degree of specificity of knowledge and skill development	
	Intra-organisational upward	Intra-organisational non-promotion	Inter-organisational upward	Inter-organisational non-promotion	Intra-occupational	Inter-occupational	Higher	Lower
ILM	√						√	
OLM			√	√	√			√

Note: The indicator of occupational mobility is only relevant to the OLM

Table 3: Types of occupational mobility and types of organisational mobility

Type of occupational mobility	Type of organisational mobility Row percentage				
	Intra-organisational upward mobility	Inter-organisational upward mobility	Intra-organisational non-promotion mobility	Inter-organisational non-promotion mobility	Overall inter-organisational mobility
Stayers in academic/public research (a)	60%	10%	11%	19%	29%
Movers' transition out of academic/public research (b)	16%	16%	13%	55%	71%
Stayers in technical positions in private sector manufacturing (c)	67%	12%	15%	6%	18%
Movers' transition out of technical positions in private sector manufacturing (d)	19%	36%	8%	37%	73%
Stayers in employment outside the conventional technical occupations (e)	37%	29%	9%	25%	54%
Movers' transitions within employment outside the conventional technical occupations (f)	32%	22%	5%	41%	63%
Overall (h)	42%	20%	9%	29%	49%

Note: Design-based descriptive data analysis. Unit of analysis = the job transition. Number of observations (a) N=29 (b) N= 12 (c) N=15 (d) N= 12 (e) N=42 (f) N= 22 (g) N=142

Table 4: Types of occupational mobility and types of skills that are perceived to be the most valuable

Type of occupational mobility	Type of knowledge and skills most useful for a job Row percentage			
	Skills acquired from PhD	Organisation-specific skills acquired from previous position	Sector-specific skills acquired from previous position	General skills
Stayers in academic/public research (a)	72%	14%	11%	3%
Movers' transition out of academic/public research (b)	31%	24%	9%	36%
Stayers in technical positions in private sector manufacturing (c)	37%	7%	19%	37%
Movers' transition out of technical positions in private sector manufacturing (d)	8%	19%	35%	38%
Stayers in employment outside the conventional technical occupations (e)	10%	19%	40%	31%
Movers' transitions within employment outside the conventional technical occupations (f)	4%	23%	46%	27%
Overall (g)	28%	20%	28%	24%

Note: Design-based descriptive data analysis. Unit of analysis = the job transition. Number of observations (a) N=29 (b) N=12 (c) N=15 (d) N=12 (e) N=42 (f) N=22 (g) N=142

Appendix Table 1: Distribution of the types of job mobility within/across career types/occupations.

Career type of previous job	Career type after job transition Data shown in percentages		
	A researcher in academic/public research	An industrial scientist or engineer in manufacturing	Employment outside the conventional technical occupations
A researcher in academic/public research	19	2	8
An industrial scientist or engineer in manufacturing	1	11	9
Employment outside the conventional technical occupations	1	2	47

Note: Design-based descriptive data analysis. Number of observations=157. Unit of analysis= the job transition

Notes

[1] This paper focuses on the career behaviour of PhD scientists and engineers from a research-based university. Modern universities incorporate the third mission at a different level and configure their activities accordingly (Larédo, 2007). For instance, industry-oriented research has been very important for universities that are not classified as research universities but focus on master's/professional training liked to regional development. It is likely that findings would differ for such types of universities.

[2] Details of the definition of a job see Lee et al (2010).

[3] At the individual level, the distribution of survey population according to gender, discipline, year of graduation and location (UK or other EU) is known. A characteristic comparison between respondents and non-respondents across these dimensions using chi-square tests for independence indicates that there is no evidence showing that respondents and non-respondents at individual level are different in gender (X^2=0.29; df=1; p=0.590), discipline (X^2=1.073; df=1; p=0.300), year of graduation (X^2=0.528; df=3; p=0.913) and location (X^2=1.113; df=1; p=0.291). At job level, as there is no information about the number of total jobs held by the surveyed PhDs - a comparison of the mean number of jobs held by each individual between the concurrent waves indicates there is no significant difference (t(97)=1.134; two-tailed p=0.260) between the number of jobs held by respondents from the first wave (mean=2.92; SE =0.130; N=79) and the number of jobs held by respondents from the second wave (mean=2.60; SE =0.245; N=20). There are very few cases of missing data due to missing information. Attrition due to such cases is assumed to be insignificant.

[4] Design-based Chi-Square test for independence, P =0.702; comparison between stayers and movers to this career type in Table 3.

[5] Details in EPSRC website: http://www.epsrc.ac.uk/SiteCollectionDocuments/other/IDCGoodPracticeGuidelines.pdf (accessed on 07 April 2011).