INGENIO WORKING PAPER SERIES

Ingenio CSIC-UPV
INSTITUTO DE GESTIÓN DE LA INNOVACIÓN Y DEL CONOCIMIENTO

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Working Paper Nº 2011/04

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The Evolution Of The Knowledge Base In Professional Service Sectors

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Abstract

The objective of this paper is to capture the extent of sectoral heterogeneity across Professional Service sectors. It is argued that ongoing scholarly disputes on their boundaries within the geography of industry have lost sight of the intrinsic diversity that characterizes these activities. The present study connects this cue to research on sectoral patterns and elaborates an empirical analysis of employment structures and the associated skill bases of professional service sectors. Through this focus we are able to frame the emergence of cross-sectoral variety in the context of evolving specialization.

Keywords:

Professional Service Sectors; Skill Intensity; Cross-Sectoral Variety

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1 Introduction

The literature on service innovation emerged during the last two decades adds to the scholarly discourse at the interface of business economics and management studies. This proliferation is testimony to the important role that service activities play in modern economies by absorbing large shares of employment and by stimulating productivity growth (Miles, 2005). Within this now sizeable body of work stands a research stream focused on activities that are commonly traded in the form of consultancy services. This literature is replete with contrasting labels (e.g. Business Services, Professional Services, Knowledge-Intensive Services), differing definitions and ongoing disputes as on where the precise boundaries lie in the geography of industry. We argue that such a debate has lost sight of the intrinsic variety that characterizes this broad class of activities (den Hertog and Bilderbeek, 2000; Tether, 2003; von Nordenflycht, 2010; Consoli and Elche-Hortelano, 2010). The present paper connects with work by Malerba (2005) on the variety of sectoral patterns to elaborate an empirical analysis of employment structures and the associated knowledge bases of professional service sectors. Our working hypothesis is that occupational structures provide important insights on the way in which activities are organised and on what types of capabilities are needed to implement them. Using data on employment in the United States (U.S.) we compute an index of skill intensity that shows how sector-specific knowledge bases grow diverse over time.

The paper contributes different realms of scholarly research. The broad aim is to advance understanding on the sources and the effects sectoral dynamics (Malerba, 2005) by adding an important, and arguably overlooked, dimension such as the organisation of the labour force. The empirical focus of the paper contributes the literature on service innovation (Miles, 2005) by offering new insights on the diversity that characterises service activities. Methodologically the paper draws attention to what data on employment and skills add with respect to the need for new indicators on the coordination of different knowledge sources (Antonelli, 2008). Finally, on a more conceptual level, the paper marks a first step in the direction invoked by organisation scholars to integrate systematically the human capital dimension in the empirical analysis (Barley and Kunda, 2001). It should be emphasised that the paper engages these different, yet complementary, matters in an exploratory fashion in the intent to propose a novel focus of analysis. The structured is as follows: section 2 lays out the conceptual framework by reviewing the literatures on industry and sectoral evolution cum knowledge growth, and on service innovation; the data analysis of section 3 is followed by a discussion on observed patters of employment and skill intensity in Section 4. The last Section summarizes and concludes.

2 Knowledge, Innovation and Organisation: the sectoral perspective

This section elaborates a synthesis of the relevant literature. The first part draws conceptual guidelines from the field of innovation studies, by looking in particular at the association between knowledge growth and sectoral patterns of development. The latter is followed by a review of the specialised literature on the chosen empirical domain, Professional Service Sectors.

2.1 Background

The field of innovation studies contributes significantly to our understanding of the intimate, yet elusive, connection between the growth of knowledge and the emergence, development and demise of activities within firms, firms within sectors, and so forth (Dosi, 1988; Nelson, 1994; Malerba and Orsenigo, 1996; Metcalfe, 2002). Central to this tenet is the notion that the life cycle of economic activities is driven by trajectories of increasing specialization. The spectrum of governance mechanisms available for coordinating different kinds of knowledge is crucial to identify latent opportunities and act strategically upon them (Nonaka and Takeuchi, 1995; Antonelli, 2008). The corollary is that economic performance is contingent on context-specific circumstances. As Rosenberg (1976) remarks, growth patterns exhibit significant variance across sectors due to differential endowments of both the formal knowledge involved and the pathways that facilitate feedback diffusion. Under this perspective, adds Nelson (1991), 'representative' firm views are ill-suited to study the impact of varieties of micro-behaviours on sectors and industries.

The empirical focus of sectors affords a good compromise for the goal of capturing broad trends of productive and inventive activities while maintaining an open window on firm-specific features. An established tradition in the community of innovation studies seeks to emphasise the diversity among the drivers of sectoral development. Such differences are ascribed to the ways in which knowledge, in the terms outlined above, impinges upon the development and adaptation of new technologies (see Pavitt, 1984; Mowery and Nelson, 1999; Malerba, 2002). This literature paved the way to studies on sectoral dynamics based on various dimensions including size of innovative firms, patterns of entry and exit, institutional arrangements, intensity of cooperative R&D, impact of R&D on productivity, cross-organisational interactions, and appropriability conditions (see Kamien and Schwartz, 1982; Pavitt, 1984; Malerba and Orsenigo, 1996; Los and Verspagen, 2004; Breschi et al., 2000; Van Dijk, 2000; Malerba and Montobbio 2003). Malerba (2005) unified these threads in the framework of sectoral dynamics by stressing interdependencies across three dimensions: (i) the knowledge base; (ii) the key actors and the networks within which they operate; and (iii) the underpinning institutional infrastructure.

This paper offers a complementary perspective by focusing on the dynamics of workforce as captured by the employment structure and the skills bases that are involved therein. We are not alone in recognising that employment structures bear on the dynamics of industrial organisation. Barley and Kunda (2001) lament that the organizational literature has paid little attention to the role of changes in work configurations. Others emphasise that occupational structures are not static but adapt to growing professionalization in the organisation of productive activities, and that as a result high-skill professionals concentrate on core management activities while ancillary tasks are assigned to support staff, either low-skilled white-collar or blue-collar workers (Caroli, 2001; Levy and Murnane, 2004; Vona and Consoli, 2009). Malhotra and Morris (2009) recently connected the literature on the sociology of professions with organization and management studies to elaborate a systematic connection between firms-level heterogeneity and the professional sector setting. Overall, they conclude, the literature on sociology has made much headway in articulating differences across professions with regards to knowledge production and use (see e.g. Abbott, 1988; Collins, 1990).

The question is: which specific aspect of employment structures is most relevant to our purpose of analysing cross-sectoral variety? Richardson (1972) speaks of (manufacturing) industries and sectors as environments where different types of transformative activities are nurtured and coordinated. Building on this we propose that each activity involves a mix of tasks that can be perfectly specified and of others that are difficult to express in terms of explicit rules. It follows that the knowledge involved in carrying out work tasks has two components: following simple rules for known instances and elaborating more complicated, partially novel, responses for unfamiliar circumstances. Skills are the fabric of routines that permit the application of knowledge to both situations (Nelson and Winter, 1982), and are our chosen unit of analysis. A skill can be defined as ability or proficiency in carrying out a specific task; skills can be acquired through formal training or developed through working experience. All skills exist insofar as humans process information however, depending on the context in which information is generated and used, it is possible to distinguish different categories of skills. Some are generic and can be applied to a broad range of tasks, others are specific to particular tasks; some skills are used to generate cognitive responses, others involve physical activities; some pertain to the individual's sphere while other skills facilitate interpersonal interaction. The methodological proposition advanced here is to explore cross-sectoral differences by looking at the repertoire of skills underpinning occupational structures.

The relevance of skills for growth and competitiveness is a latent thread that cuts across different strands of literature. Early traces in the scholarly work on innovation can be found in studies on the importance of information exchange (Rothwell et al., 1974), on employment participation (Kline and Rosenberg, 1986) and on complementary assets (Teece, 1986). These themes have been further articulated with respect to the dynamics of the firm and the strategic coordination of different kinds of knowledge in the management literature (Cohen and Levinthal, 1989; Kogut and Zander, 1992). A handful of empirical studies ascribe differences in firm performance to the accumulation of knowledge and skills (Geroski et al., 1993; Henderson and Cockburn, 1996; Johnson et al, 1996; Leiponen, 2005). More fine-grained works elucidate the mutual influence between types of skills and forms of innovation. A study by Leiponen (2000) on manufacturing firms in Finland finds that research skills benefit firm profitability insofar as the level of general skills is sufficiently high; Freel (2005) indicates the association between specific categories of skills and types of innovators among small UK-based enterprises; a cross-industry analysis by Lavoie and Therrien (2005) emphasises how different categories of workers respond to the adoption of new technologies according to their skill endowment; Neffke and Henning (2009) estimate a strong impact of skills (computed indirectly through labour flows) on decisions to diversify decisions across industrial sectors in Sweden; Giuri et al (2010) present evidence of positive association between skill heterogeneity and performance in collective Open Source projects.

Another strand of literature focuses on the extent to which employees participate directly in work activities and what this reflects on the quality of employment. This theme has been approached from radically different angles. Some take the long view and praise the increasing trend of skill levels associated to technology diffusion in advanced economies (Blauner, 1964; Kerr *et al.,* 1960; Piore and Sabel, 1984; Zuboff, 1988). A managerial strand focuses on the benefits of employee involvement in decision-making as a mechanism for improving work performance and organizational productivity (Marchington and Wilkinson, 2000; Walton, 1985; Wilkinson, 2002). Others advocate that changes in managerial practices and in the organization of production triggered by the adoption of new technologies induce deskilling and phenomena of ‘alienation’ at work (Braverman, 1974; Crompton and Jones, 1984; Friedmann, 1946). Yet another strand of research calls attention to the polarization of the workforce, namely the divide between those who benefit from upskilling and those whose skills either stagnate or decline (Berger and Piore, 1980; Gordon *et al.,* 1982). Recent empirical work ascribes this diversity of views to the specificities of the attending institutional setups. A cross-country comparison by Gallie et al (2004) for example focuses on the mutual influence among trade union participation, modes of production and systems for skill formation. The key finding is that high skill polarization in Britain and Spain stands contrasts with the convergence observed in Sweden, France and Germany. The most significant factor behind these differences is the institutional system of skill formation: high polarization is stronger in countries whose skill formation has a generic orientation while workers trained in countries with schools-based specific skills enjoy greater protection against the risk of deskilling and skill polarization (see also Gallie et al, 2003).

Yet another established stream within the economics literature ascribes trends of productivity growth to mutual interactions between skill levels and waves of disruptive technical change (see e.g. Galor and Moav, 2000; Acemoglu et al., 2002; Goldin and Katz, 2008). Two specific contributions in this area connect explicitly changes in employment patterns to the pools of workers' skills.[2] An analysis of the impact of computerization on the demand for skills by Autor et al (2003) shows that the widespread adoption of ICTs associates to higher demand for non-routine cognitive and interpersonal skills, to lower demand for routine analytical skills and that it has negligible impact on the demand for manual skills. Still focussing on the wave of ICT adoption in the U.S. economy Levy and Murnane (2004) observe significant increase in the importance of expert thinking – i.e. cognitive skills aimed at non-routine jobs such as detecting uncharted patterns – and of complex communication – i.e. skills needed to engage non-routine interactions. These insights indicate that the ICT adoption has triggered a profound transformation of the content, the

[2] This literature is voluminous, and a full review is beyond the scope of the present paper. See systematic reviews of these themes: Tether et al (2005), Violante (2007) and Vona and Consoli (2009).

structure and the relevance of occupations. What is more, the generalised increase of minimal level of cognitive skills blurs the archetypal distinction between manual and cognitive jobs.

The present study draws on and adds to these different streams of literature by offering an intermediate perspective between firm-level and economy-wide. All the foregoing threads are brought together under the conjecture that there exists a close match between occupational structures and the associated skill bases. In particular we propose that the extent of task partitioning and the correlated adaptations in the composition of the workforce and the skill base depend on the nature and the relative importance of problem-solving activities. To the extent that individual knowledge is imperfectly reflected in the activities that make up any sector, it is argued that occupations are mechanisms for coordinating particular repertoires of skills vis-à-vis explicit task structures. In this view occupations are considered as vectors of skill-task co-occurrences specific to each sector. These conjectures are probed empirically through an empirical analysis of Professional Service Sectors, a set of activities whose distinctive character sits well among various issues raised so far.

2.2 Service Innovation and Professional Services

A vast, and ever-growing, body of literature contributes our understanding of the main characteristics of service activities, in particular: the information-based nature that is strongly associated to the use and development of Information and Communication Technologies; the close interaction between providers and users due to flexibility of services; the importance of human resources and skills for innovative service activities (Miozzo and Soete, 2001; Tether, 2003; Drejer, 2004; Miles, 2005; Consoli, 2007). From this sizeable body of empirical and theoretical research stems a strand dedicated exclusively to Professional Services (PSs), that is, activities of knowledge screening, assessment and evaluation that are traded in consultancy markets.

The existing literature offers a wide assortment of perspectives on PSs. Organisation theorists emphasise the role of power relations within professional service firms (Barley, 2005; Blau & Scott, 1962); management-oriented work focuses on the contribution of individual professionals on firm performance (Greenwood et al., 1990; Hinings et al, 1991; Maister, 1993; Winch and Schneider, 1993); Miles et al (1995) from the innovation studies camp propose the label Knowledge Intensive Business Services (KIBS) to study firms whose business is the creation, accumulation and dissemination of knowledge. The latter perspective focuses on the knowledge component of these service activities and has been the most successful in establishing a unified and at the same time broader view beyond the canonical examples of law and accounting firms (see review by Mueller and Doloreux, 2008).

By and large, and regardless of the label adopted, the rise and expansion of professional services is widely regarded as a physiological step in the maturation of modern economies characterised by rising levels of per capita income and finer specialisation (Antonelli, 1998; Hipp, 1999; Den Hertog, 2000; Muller and Zenker, 2001; Kuuisto and Meyer, 2003; Pavitt, 2005; Castellacci, 2008). What is perhaps less debated is that the structure of knowledge underpinning these economies is not isomorphic with respect to the organisation of industries and sectors. This paper focuses on the problem-solving nature of professional service activities, and on the organisational processes that stem from and in turn influence their business conduct.

Professional Service Sectors rely heavily on tacit knowledge embodied in their employees as well as on codified knowledge, which is both input for and output of such activities. Their core competence is the integration of different forms of knowledge into tradable output. Some activities, let us call them Type 1, do not imply changes on the content of information but merely the maintenance of infrastructures for transmission. Others, let us call them Type 2, have a transformative nature and consist in trading newly created information packages (Salter and Tether, 2006). The upshot is that the former types of services are more amenable to standardization compared to Type 2. This remark resonates with Herbert Simon's (1969) distinction between 'semantically-rich domains'– like architecture or business consultancy – that rely on task-specific information and non 'semantically-rich domains' – like technical assistance or maintenance – wherein task structures are more standardized and professional discretion is lower. In the latter the repertoire of problem-solving options is known ex-ante with a finer degree of precision, and replication of existing routines through non-cognitive skills suffices. The attendant task structures of Type 1 services are less amenable to standardization because problem-solving strategies are normally generated in the context of client-supplier relations, and this reduces the replicability of learned solutions (Simon, 1969).

It is important to clarify that 'problem-solving' is used here to refer to a broad class of cognitive processes that identify and remove obstacles in the implementation of goal-driven activities – like work tasks. This resonates with the view that decision-making, both for individuals and business firms – entails confronting routines, decision rules, procedures and incentives that are known and understood only in part. Problem-solving entails the adoption of trial-and-error procedures to select locally satisficing options. By reducing large combinatorial spaces of possibilities to a manageable scale, problem-solving operates like a compass while exploring the complex landscapes of decision-making. Thereby while not all problem-solving activities induces directly innovations, the vast majority of innovations are achieved by engaging some degree of problem-solving.[3]

Building on these premises we propose to explore differences across patterns of learning, occupational structures and the associated skill bases of professional services. Businesses whose main task is tailoring solutions around clients' specific requirements require high degrees of openness and networking and depend more tightly on the knowledge and expertise of specific employees (Hitt et al, 2001; Muller and Zenker, 2001; Lowendhal et al, 2001; Kuuisto and Meyer, 2003). The typical task structure of this class of services includes a mix of general knowledge,

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[3] We thank an anonymous referee for calling our attention to this point.

practical problem-solving and on-the-job learning (Bettencourt et al., 2002; Miles 2005). The associated skill bases encompass cognitive skills such as creative response, critical thinking as well as social skills to achieve good comprehension of the problem at hand by to keeping close relations with the clients. This pattern of specialisation differs considerably from that observed in technical assistance-type of activities.

Against this backdrop exists an interesting dualism in the literature. On the one hand are studies that establish with clarity the extent of heterogeneity of PSs both in terms of sectoral growth rates across countries and of cross-sectoral specialization within countries (Antonelli, 1998; Muller and Zenker, 2001; Freel, 2006; Zenker and Doloreux, 2008; Corrocher et al, 2009). Another part of the literature is instead preoccupied with getting the boundaries right in the geography of industry thus contributing to a paradoxically homogeneous view of these services (den Hertog and Bilderbeek, 2000; Tether, 2003; von Nordenflycht, 2010; Consoli and Elche-Hortelano, 2010) which overlooks the role of sectoral specificities for innovation (Zenker and Doloreux, 2008; Amara et al, 2009; Corrocher et al, 2009). The remainder of the paper tackles these themes by analysing the occupational structures and skill requirements of professional service sectors.

3 Empirical analysis

The centrality of knowledge growth in the evolution of sectors and industries has been emphasised in the preceding pages. To operationalise these insights let us recall from the literature review the notion that in each sector employment structures reflect purposeful commitment of human resources to an ensemble of context-specific tasks. Our proposition is that the repertoire of skills that are embedded within occupational structures captures the distinctive combinations of knowledge underpinning the operation of each sector. Bearing in mind the conceptual framework outlined above this section seeks to address two questions:

1. What occupational structures emerge in Professional Service sectors? And do these differ across such sectors?

2. What knowledge bases, as inferred from the demand for skills, prevail in each of the sector under analysis over time? And, to what extent do these differ?

3.1 Data description

This study draws on two main data sources, the Industry-Specific Occupational Employment Estimate of the U.S. Bureau of Labor Statistics (BLS)[4] and the survey on abilities 'Occupational Information Network' (O*NET).[5] From the former we extract information on the employment structures of Professional, Scientific and Technical Services (NAICS code 54); the second contains standardized information collected by means of annual surveys whereby respondents assign a score to a wide range of attributes and characteristics of occupations (as coded in the BLS). By combining the two sources we construct a dataset where each occupation in a sector (as extracted from the BLS) is defined by a vector of skill scores (listed in Appendix A) and Standard Vocational Preparation (SVP) level (both contained in O*NET). The sample used here consists of 11 sectors (listed in Appendix B) whose occupational structures and skill contents are measured at three points in time in the years 2000, 2005 and 2009.

Let us address the first of the two questions above about the employment structures of professional service sectors. Table 1 contains descriptive information for years 2000, 2005 and 2009. The first indication is that overall employment in this group of sectors has fallen by 11% throughout the decade (first block of columns, Total Employment). A comparative look suggests that Accounting is the only sector exhibiting steady growth of the labour force throughout the whole decade (+30% in 2009) while others feature a decrease in the first half of the decade followed by increase – i.e. Computer System Design, Consulting, Other Professional Services and R&D. Advertising, Architectural and Legal Services show an opposite trend. Engineering and Testing only appear in the statistics in the second period and show +10% the former, -11% the latter (employment figures

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[4] http://www.bls.gov/oes/current/oessrci.htm#54

[5] See Appendix A for further details.

for Architectural, Engineering and Testing Services are grouped in a unique category for year 2000 in the BLS database). The second broad indication is that the general level of skills measured by Mean Educational Requirement has increased by 0.3 throughout the decade in aggregate (second block of columns). Herein the strongest increase can be observed in Design Services (+2.8) and, to a lesser extent, in Other Services and R&D while mean values are lower for Legal, Architectural and Accounting Services.

A look at the breakdown of occupational categories indicates a decrease, 23% to 2%, of unskilled employees across all sectors. In aggregate the structure of occupation shows a significant increase of intermediate-skill category, from 12% to 30%. The far-right block of Table 1 details employment distribution in percentage terms across sectors and by type of occupation. Here we observe that employment among the *low-skilled* falls across all sectors, more so in Design (-67%) and Other services (-40%); the data also reveal that this category of workers almost disappears in Computer System Design an Legal Services by count of 2009. Employment among *intermediate-skilled* occupations experience generalized increase, more remarkably in Architectural (despite the disaggregation from Engineering and Testing), Legal services, and Other services. Moving on to the upper echelons of the occupational structure, *high-skilled*, grows in Design (+47.97%), Other services, R&D and to a lesser degree in Computer Systems, Consulting, Engineering and Testing (comparing 2005-2009) while it decreases in Architectural (-32.76%), Legal (-18.46%), Accounting and Advertising Services.

TABLE ONE ABOUT HERE

To sum up, the analysis of the employment structure over the decade 2000-2009 reveals three sectoral groupings:

1. Services in which the share of high-skilled workforce is higher, namely R&D, Computer Systems, Engineering and Management Consulting;

2. Services whose workforce is predominantly made of intermediate-skilled workers such as Legal Services, Testing, Accounting, Advertising and Other;

3. Services like Architectural and Design featuring a balance between the former two categories of workers.

3.2 Data Analysis

Let us now turn to the second question concerning the analysis of the skill bases of professional services sectors. To this end we compute from O*NET data an index of skill intensity based on the score assigned to respondents to each of the skills for each of the professions in the sector; the score is weighted by the number of years in excess of High School (calculated from the SVP level which is unique to each profession) and standardized by the total employment of all professional services sectors:

$$SK_i^{\,j} = \ln\left[\frac{\sum s_{i,j}^{z}}{N}\,\varepsilon_i\right]$$

where

i = occupation per sector; $j = 1, \ldots, 11$ (sectors); $z = y = 1, \ldots, 36$ (O * NET skills)

$s_{i,j}^{z}$ = score assigned by survey respondents to skill z for profession i in sector y

ε_i = years of education in excess of High School

$\mathrm{N} = \sum_i \sum_j n_{ij}$ (Total employment across industries)

For each year of observation there are as many SK values as the number of occupations per sector. In order to extract meaningful patterns the SK indexes are used as inputs for multivariate data reduction. This exercise identifies two factors that are robust across all sectors and over the three time periods (2000, 2005 and 2009), and that explain a large percentage of the variance (Table 2). The Chi-sq. test confirms that the goodness of fit is significant at conventional levels.

Factor 1 is interpreted as a broad measure of cognitive skills. Looking at Table 2 we note that the factor loads very high on variables measuring Interactive (e.g. Negotiation, Social Receptiveness), Communication (e.g. Instructing, Persuasion) and mostly non-routine type of skills (e.g. Active Learning, Critical Thinking, Complex Problem Solving); together with these are also some complex routine-skills such as Management of Personnel and Coordination. Overall this group matches the profile of upper-level employees, for example in a management capacity. Factor 2 on the other hand loads high on items that can be assimilated to manual activities such as Repairing, Troubleshooting and Installation but includes also Science, Programming and Technology Design. While the observed distribution of skills across the two factors resonates with the claim that cognitive skills play a growing role in across the whole professional sphere (Levy and Murnane, 2004; Vona and Consoli, 2009), differences exist in the cognitive content.

TABLE TWO ABOUT HERE

For illustrative purposes we plot the distribution of sectors in the factor space by taking the average scores of the two factors for the three years under analysis (Diagrams 1a, b and c). The first indication of the scatter diagrams is that Factor 1, Cognitive Non-Routine skills (in the horizontal axis), scores low in the first period and grows progressively in the remaining years. In fact in year 2000 most sectors are located on the left half of the diagram (Fig. 1a), thus indicating low scores in both factors (i.e. Legal, Advertising, Accounting and Other) or comparatively higher intensity of Factor 2 (Cognitive Routine skills, in the vertical axis) as is the case for Design and Computer System Design and, slightly less, for Architectural, R&D and Consulting. The snapshot of year 2005 (Fig. 1b) captures a number of interesting changes: some sectors score higher in Factor 1 – Computer System Design, Consulting and Design – while Legal services have the highest factor intensity for Cognitive Routine skills. The sector clustering observed in 2009 (Fig. 1c) shows the continuity of this pattern as Computer is now close to Engineering, Consulting and Advertising in the region of high intensity of Cognitive Non-Routine skills, while a higher score of Cognitive Routine skills brings Accounting closer to Legal services.

FIGURE ONE a,b,c ABOUT HERE

Let us turn to the association between skill categories and sectors. Recall from Section 2 that in our proposed conceptual framework occupational structures are understood as mechanisms for coordinating repertoires of skills and sector-specific tasks. Therefore once identified how skills group together the next step is to investigate how these distribute across the sectors under analysis. To this end we propose a multinomial logit model to estimate the strength of association between the skill factors (explanatory variables) and their observed intensity in each of the professional service sectors (dependent variable). Results for years 2000, 2005 and 2009 are presented in Table 3. Model diagnostics confirm the overall goodness of fit of the model. In the upper part of the Table are estimated coefficients which, it is worth reminding, in a multinomial logit measure the proportional change in the log of the odds-ratio of the dependent variable (one of the sectors) when the regressor (skill intensity) changes by one unit; put another way, a positive (or negative) coefficient implies that the odds of that response category increases (or decreases) by a factor which is equal to the odds ratio (Exp(B)) for any unit change of the regressor (see Scott-Long, 1997). The reference group for the dependent variable is the residual category, Other Services.

TABLE THREE ABOUT HERE

In the first period the odds of a unit increase of intensity of Cognitive Non-Routine skills (Factor 1) are lower for Architectural (whose occupational structure is grouped together with Engineering and Testing in the first year), Consultancy and R&D compared to Other Professional Services, with rather similar odds ratios. The odds of higher Cognitive-Routine skills intensity are 24% higher for Architectural, 30% for Computer System Design and 63% for Professional Design relative to the reference group. Overall, the occupational structures of Professional services exhibit lower intensity of Non-Routine compared to Routine skills in this first year. The estimated coefficients for 2005 differ from the previous in that now Advertising, Design (albeit with a rather small odd-ratio), R&D (again and with a similar odd-ratio compared to 2000), and Testing are negatively associated with Non-Routine skills; the odds of higher Non-Routine Skill intensity are now higher for Computer

System Design, albeit by a weak 23%. Legal Services features a positive coefficient for the Routine skill group. The trend changes towards the end of the decade as the estimated coefficients for the Non-Routine cognitive skills are positive for Advertising, Computer System Design, Consulting and Engineering, the latter two with the highest odds-ratios. At the same time the odds of a unit increase of Non-Routine skills are lower for Architectural, Design, Engineering, R&D and Testing.

4 Discussion

The empirical analysis of the previous section sought to address two questions: (1) Do employment structures differ across sectors? And, (2) do the prevailing types of knowledge, as captured by profession-specific skills, differ across sectors? The answers to both are affirmative. Professional Services do exhibit substantial diversity both in the composition of the workforce and in the associated knowledge bases. This finding may well appear trivial but, given the discussion in Section 2.2., it sets the record straight on an aspect that seems to have escaped the attention of the specialised literature: while the core competence of producing tradable information outputs has the character of generality across most Professional services, the types of knowledge involved and the pathways through which the relevant knowledge is applied reveal some degree of specificity. The analysis presented here hinges upon a functional difference between Type 1 service activities consisting mostly in the transmission of information without making any changes, and Type 2 activities whose ultimate goal is instead modify previous information and create new one. For what concerns the competences involved, the first type thrives upon the application of repetitive routines while the second entails the implementation of novel problem-solving strategies around the tasks at hand. The upshot is that Type 1 services employ more intensively skills that facilitate the standardization of routines while Type 2 skills with stronger cognitive content to accommodate customized response.

A look at the fabric of skills for three years – 2000, 2005 and 2009 – delineates interesting dynamics. Contrary to a consolidated perception Professional Services are not the exclusive realm of high-skilled professionals. Indeed the breakdown of employed workforce by levels of educational requirement and by job level (Table 1) captures two groupings. In the first are sectors whose largest share of the workforce is employed in occupations involving intermediate levels of skills: Legal Services, Testing, Accounting and Advertising. This resonates with the reality of these sectors, perhaps with the exception of Advertising, where most activities revolve around the application of preordained rules given perhaps some margins of creativity in interpreting them (Malhotra and Morris, 2009). Conversely high-skilled professionals dominate the workforce of the other group of sectors – R&D, Computer System Design, Engineering and Consulting – that usually confront open problems, that is, situations that are best dealt with by mixing creativity with limited reuse of past experience. The first grouping matches the Type 1 profile, the second that of Type 2. These indications are reinforced by the analysis of the associations between the skill factors and their observed intensity in each of the professional service sectors. The multinomial logit analysis (Table 3) confirms the significant role of Cognitive Non-Routine skills (compared to the residual category Other professional Services) in Type 2 sectors – Computer Systems, Consulting and Engineering – plus Advertising. This association resonates with the professional style of these services in which creative and interpersonal skills play a pivotal role. The statistical exercise highlights an equally plausible association between Type 1 sectors, Legal and Accounting, and Cognitive Routine skills. This is interpreted as indicative of growing routinization in the array of activities involved along the lines suggested by Autor et al (2003).

The other unambiguous indication of the factor analysis (Table 2) and the logit regression (Table 3) is that cognitive skills are strongly complementary to both routine and non-routine activities (Levy and Murnane, 2004). This is relevant beyond the immediate remit of this paper. Before the ubiquitous adoption of ICTs altered drastically the kernel of work organization (David, 2000) it was acceptable to differentiate sharply cognitive and non-cognitive tasks, the latter associated mostly to manual activities. But the new regime has given way to patterns of organization in which the dichotomy between manual and non-manual has vanished. While this may be a somewhat expected result in information-intensive contexts like professional services, wherein the share of manual-only tasks is presumably low, our results highlight an interesting differentiation between cognitive skills that complement each other, as those that make up Factor 1, and cognitive skills that complement manual-type of skills like those in Factor 2. Looking in specific among the latter items like Science, Operation and Control and Programming play an enabling role for Repairing, Installation, Equipment Maintenance and so forth. An interesting question for future research is understanding the extent to which these forms of skill complementarities are sector-specific, and how these look like in different contexts. Together with the clear-cut results outlined above we observe cases in which the coefficients suggest negative associations between skill type and sector – i.e. between Cognitive Routine skills and R&D, Testing and Design. The only anomaly observed here are the significant and negative coefficients of Architectural service sector in both skill groups. Finally it is instructive to observe how configurations change over time like, for instance, the skill profile of Architectural Services and Design that is clearly defined at the beginning of the decade (positive and significant coefficient for Cognitive Routine skills) but dilutes towards the end. The converse holds for a large group of sectors whose skill profile is indefinite in 2000 but becomes definite in 2009.

5 Concluding remarks and the way ahead

Let us pull together all the threads and reflect on the contributions of this paper. First, the empirical study lends support to the conjecture of diversity across Professional Service sectors that went amiss in some parts of the specialised literature. The method used to explore cross-sectoral heterogeneity is the second contribution of the present work: the central idea is that the activities that make up sectors entail task configurations that call upon particular combinations of skills embedded in the occupational structures. This particular focus resonates with and adds to the sectoral systems framework (Malerba, 2005) by proposing that employment structures are instituted mechanisms to facilitate the application of workers' knowledge to a set of sector-specific tasks. This prominence of labour market dynamics for the development of sectors calls attention to an aspect that has escaped the attention of innovation scholars. Yet another contribution is the practical reading of how knowledge impinges upon sectoral dynamics not in abstract but rather in terms of practical application of learned routines. This resonates with Rosenberg's (1976: 86) remark about the role of 'qualitative changes in the human agent as a factor of production' and the centrality of individual learning processes that has found its place in some literature (Howell and Wolfe, 1992; Autor et al, 2003; Neffke and Henning, 2009; Giuri et al, 2010).

Looking ahead, we propose that the present paper points to some interesting avenues for future research. First, the empirical analysis draws attention to a rich and hitherto unexplored data source with considerable potential well beyond studies on services sectors. Availability of survey data on skills collected straight from the source – i.e. employees and employers – like O*NET is a promising step towards addressing the need, voiced by many, for new indicators on knowledge dynamics.[6] Second, the analysis of skill structures opens an important window on policy issues concerning skill mismatches, knowledge gaps and the role of education policy in responding to emergent industry needs. As the European Commission (2008) recognizes, fast technological change and employment patterns driven by globalization trigger skill shortages as well as oversupply. While US data are, to the best of our knowledge, the most complete source, we follow with interest analogous initiatives in Europe.[7] On a conceptual level we find that both the object and the method of study of this paper present evolutionary-minded scholars with insights worthy of further development. In a nutshell we hint at the notion of sectors as ecologies of professions whose

[6] The survey data Sourceforge.net on Open Source developers is broadly similar. See Giuri et al (2010).

[7] Comparable initiatives for data collection in Europe are still at primordial stage. See e.g. http://www.cedefop.europa.eu/EN/Information-services/vet-bib-bibliographic-database.aspx; or http://www.eskills-monitor.eu/. See Cedefop (2009).

combinations of characteristics, viz. skills, determine their relative fitness. The underpinning evolutionary dynamics is such that the distributions of population characteristics change as a result of learning by micro-agents. Accordingly, over the long run, we would expect to observe differential growth of these characteristics driven by the emergence of new combinations of skills and the demise of others (Nelson and Winter, 1982; Dosi, 1988; Metcalfe, 1998). The availability of micro-longitudinal data such as those used here bodes well for this endeavour. At the same time it is worth stressing that the analysis of this study is limited to three years, and thus offers a partial view of the co-evolution between occupational structures and the associated skill bases. Future research based on longer data series may further elucidate patterns of sectoral specialisation and, in particular, the mutual adaptation between skill repertoires and task configurations.

Let us conclude by referring to a broader question. This work claims novelty for having looked at knowledge dynamics through the lenses of employment structures. Is this approach novel because the dynamics of the labour market have been sidelined in innovation studies? If we agree that labour is, at the core, application of knowledge to specific tasks, and given that innovation scholars handle knowledge routinely, our paper should not have, after all, fallen too far from the tree.

Acknowledgements. We would like to thank the administrators of the National Center for O*NET Development for making data available. We thank participants at the 6th Iberian International Business Conference (Universidad Autonoma de Barcelona, Spain) and at the Stan Metcalfe Festschrift (University of Manchester, England) for comments on a preliminary version of this manuscript. The remarks by Stan Metcalfe, Peter Allen, Cristiano Antonelli, Franco Malerba, Franco Montobbio, Pier Paolo Saviotti and Ulrich Witt are gratefully acknowledged. D. Consoli acknowledges financial support from the European Community (FP7-PEOPLE-IEF-2008-235278). The usual caveats apply.

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	Total Employment (000s)			*Mean Educational Requirement*[8]			*Low-skill (%)*			*Intermediate (%)*			*High-Skill (%)*		
	2000	*2005*	*2009*	2000	2005	2009	2000	2005	2009	2000	2005	2009	2000	2005	2009
Legal Services	978	1143	1126	5.15	4.48	4.6	10.16	0.98	0.38	34.26	62.62	62.49	55.59	36.41	37.13
Architectural	880	1207	317	5.02	4.14	4.7	5.05	2.38	3.14	13.37	47.22	48.04	81.58	50.41	48.82
R&D	492	431	529	3.94	4.58	5.05	16.74	1.81	0.95	28.19	34.73	31.13	55.07	63.46	67.92
Computer System	1962	522	1364	4.13	4.2	4.16	6.03	0.41	0.16	28.03	31.93	29.55	65.94	67.66	70.29
Engineering	-	119	842	-	4.16	4.02	-	1.25	0.70	-	43.22	40.77	-	55.53	58.54
Consulting	940	395	889	3.4	3.72	3.67	17.26	4.68	1.33	31.10	44.27	43.19	51.64	51.05	55.49
Testing	-	921	126	-	3.7	3.47	-	2.51	0.96	-	50.29	53.68	-	47.20	45.37
Accounting	597	751	843	3.51	3.19	3.19	9.53	1.47	0.59	33.74	54.82	54.82	56.73	43.71	44.60
Advertising	259	749	407	3.02	2.78	2.85	16.46	13.53	1.70	39.51	48.64	60.86	44.03	37.82	37.43
Design	1624	753	121	0.93	3.07	3.5	69.72	6.04	2.46	22.32	51.20	41.61	7.96	42.75	55.93
Other	158	132	554	1.13	2.65	2.7	42.00	2.22	1.39	50.61	78.66	75.40	7.39	19.12	23.22
Tot	**7890**	**7125**	**7119**												

Table 1: Total employment, Mean educational requirements, occupational volume and structure (%)

[8] Mean of minimal number of years of Education post High-School required.

2000			**2005**			**2009**		
	Fact_1	Fact_2		Fact_1	Fact_2		Fact_1	Fact_2
Negotiation	**0,8899**	0,4045	Negotiation	**0,8595**	0,4772	Writing	**0,8665**	0,4837
Managem. Fin. Res.	**0,8871**	0,3486	Persuasion	**0,8589**	0,4823	Negotiation	**0,8628**	0,4857
Persuasion	**0,8865**	0,4205	Soc. Perceptiveness	**0,8585**	0,4799	Persuasion	**0,8587**	0,4954
Soc. Perceptiveness	**0,8807**	0,4090	Managem. Fin. Res.	**0,8525**	0,4439	Soc. Perceptiveness	**0,8578**	0,4945
Manag. Pers. Res.	**0,8639**	0,4151	Service Orientation	**0,8423**	0,4688	Speaking	**0,8551**	0,5079
Time Management	**0,8512**	0,5015	Manag. Pers. Res.	**0,8413**	0,4874	Managem. Fin. Res.	**0,8494**	0,4380
Speaking	**0,8394**	0,5277	Speaking	**0,8401**	0,5283	Service Orientation	**0,8484**	0,4992
Coordination	**0,8363**	0,5238	Time Management	**0,8373**	0,5282	Active Listening	**0,8455**	0,5218
Service Orientation	**0,8243**	0,4097	Writing	**0,8342**	0,5295	Read. & Compr.	**0,8419**	0,5270
Writing	**0,8242**	0,5398	Active Listening	**0,8293**	0,5458	Time Management	**0,8410**	0,5293
Active Listening	**0,8235**	0,5456	Monitoring	**0,8226**	0,5570	Judg. Decis. Mak.	**0,8380**	0,5348
Judg. Decis. Mak.	**0,8179**	0,5562	Judg. Decis. Mak.	**0,8199**	0,5593	Critical Thinking	**0,8369**	0,5403
Systems Analysis	**0,8163**	0,5634	Coordination	**0,8187**	0,5621	Monitoring	**0,8345**	0,5414
Monitoring	**0,8133**	0,5674	Critical Thinking	**0,8141**	0,5704	Active Learning	**0,8270**	0,5556
Systems Evaluation	**0,8127**	0,5420	Learning Strategies	**0,8122**	0,5680	Manag. Pers. Res	**0,8203**	0,5339
Comp. Prob. Solv.	**0,8017**	0,5871	Active Learning	**0,8114**	0,5740	Coordination	**0,8190**	0,5626
Learning Strategies	**0,7955**	0,5843	Instructing	**0,8073**	0,5589	Learning Strategies	**0,8158**	0,5637
Active Learning	**0,7949**	0,5881	Read. & Compr.	**0,8051**	0,5739	Comp. Prob. Solv.	**0,8116**	0,5700
Manag. Mat. Res	**0,7928**	0,5631	Comp. Prob. Solv.	**0,7809**	0,6052	Instructing	**0,8058**	0,5752
Instructing	**0,7904**	0,5594	Manag. Mat. Res	**0,7544**	0,6124	Mathematics	**0,7994**	0,5732
Critical Thinking	**0,7876**	0,5983	Operat. Analysis	**0,7516**	0,6254	Operat. Analysis	**0,7808**	0,5839
Read. & Compr.	**0,7851**	0,5983	Mathematics	**0,7507**	0,6230	Systems Evaluation	**0,7419**	0,6389
Mathematics	**0,7310**	0,6330	Systems Evaluation	**0,7309**	0,6413	Manag. Mat. Res	**0,7362**	0,6295
Operat. Analysis	**0,7209**	0,6518	Systems Analysis	**0,6996**	0,6661	Quality Contr. An.	**0,7110**	0,6731
Equip. Maintenance	0,4013	**0,8858**	Repairing	0,4242	**0,8737**	Systems Analysis	**0,7040**	0,6770
Op. Monitoring	0,4268	**0,8824**	Equip. Maintenance	0,4410	**0,8637**	Repairing	0,4080	**0,8886**
Troubleshooting	0,4161	**0,8784**	Op. Monitoring	0,4579	**0,8593**	Equip. Maintenance	0,4235	**0,8792**
Repairing	0,4224	**0,8662**	Installation	0,5006	**0,8287**	Op. Monitoring	0,4895	**0,8412**
Installation	0,4264	**0,8586**	Operat. & Control	0,5648	**0,7934**	Installation	0,5266	**0,8194**
Technology Design	0,5096	**0,8154**	Troubleshooting	0,5834	**0,7868**	Operat. & Control	0,5783	**0,7874**
Science	0,5048	**0,7858**	Technology Design	0,6017	**0,7580**	Troubleshooting	0,6361	**0,7591**
Quality Contr. An.	0,6037	**0,7858**	Science	0,5743	**0,7353**	Technology Design	0,6746	**0,7064**
Operat. & Control	0,5712	**0,7794**	Programming	0,5488	**0,7352**	Equip. Selection	0,6965	**0,6994**
Equip. Selection	0,6301	**0,7603**	Equip. Selection	0,6714	**0,7246**	Science	0,6491	**0,6695**
Programming	0,5278	**0,6975**	Quality Contr. An.	0,6669	**0,7200**	Programming	0,6231	**0,6664**
% of var. explained	54.052	40.580		54.748	40.850		57.332	38.994
Cumulative % expl.	54.052	94.633		54.748	95.598		57.332	96.325
χ^2 test	83.323 (.000)***			82.966 (.000)***			72.975 (.000)***	

Exploratory Factor Analysis with Principal Components as the initial factor method
Rotation method: Orthogonal Varimax with Kaiser normalization
Significance levels: *** 0.01; ** 0.05; * 0.10

Table 2: Factor Analysis

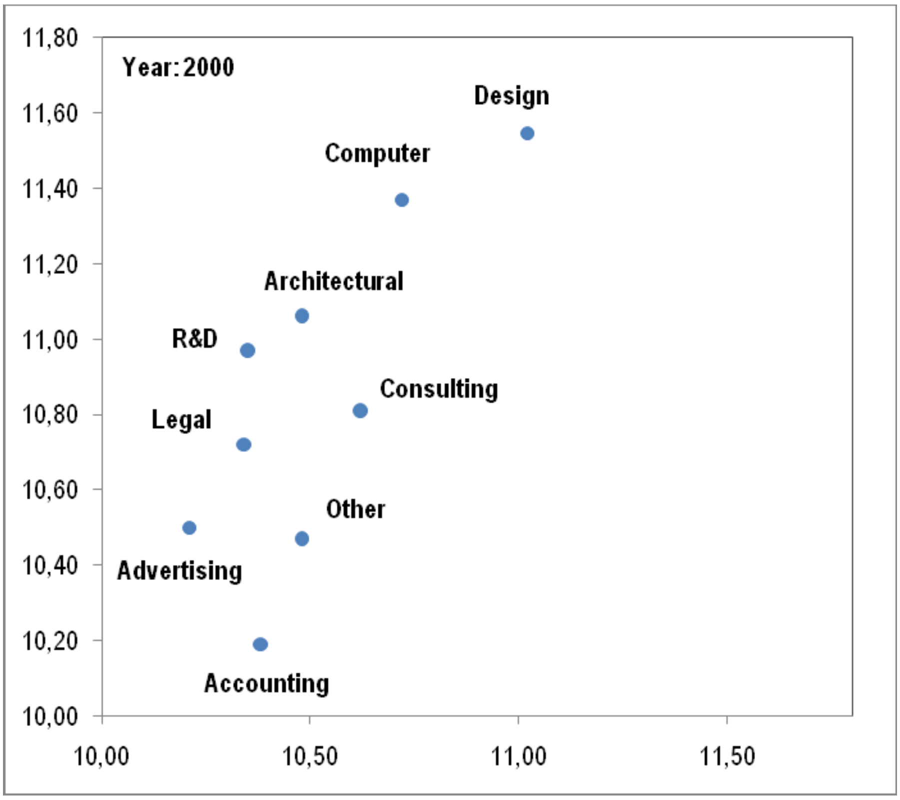

Figure 1a: Distribution of Sectors in factor space, year 2000

(Average Factor 1 in horizontal axis; Average Factor 2 in vertical axis)

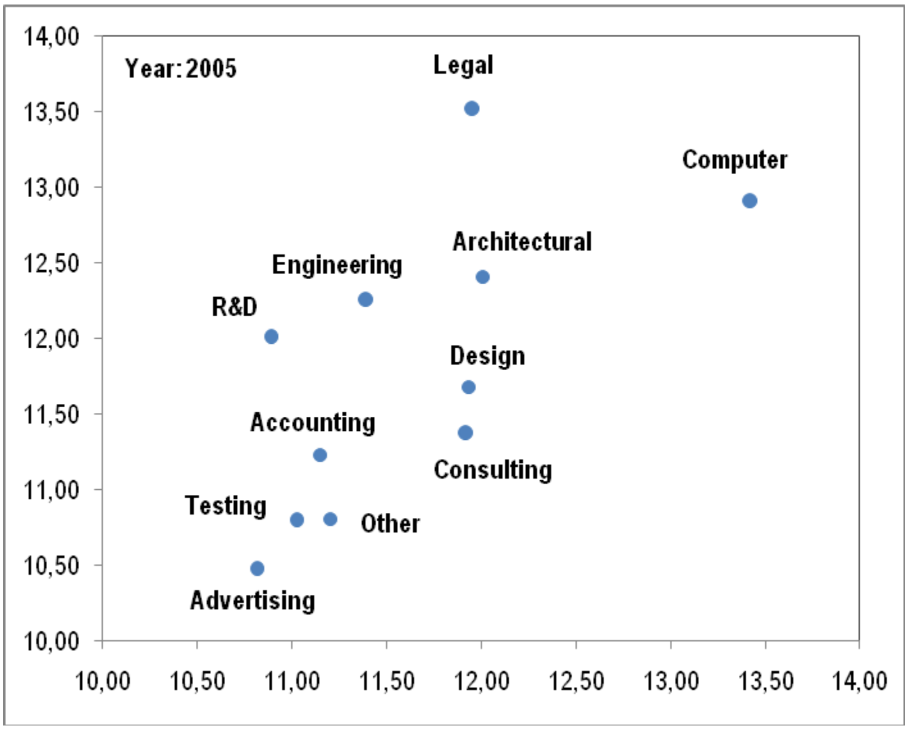

Figure 1b: Distribution of Sectors in factor space, year 2005

(Average Factor 1 in horizontal axis; Average Factor 2 in vertical axis)

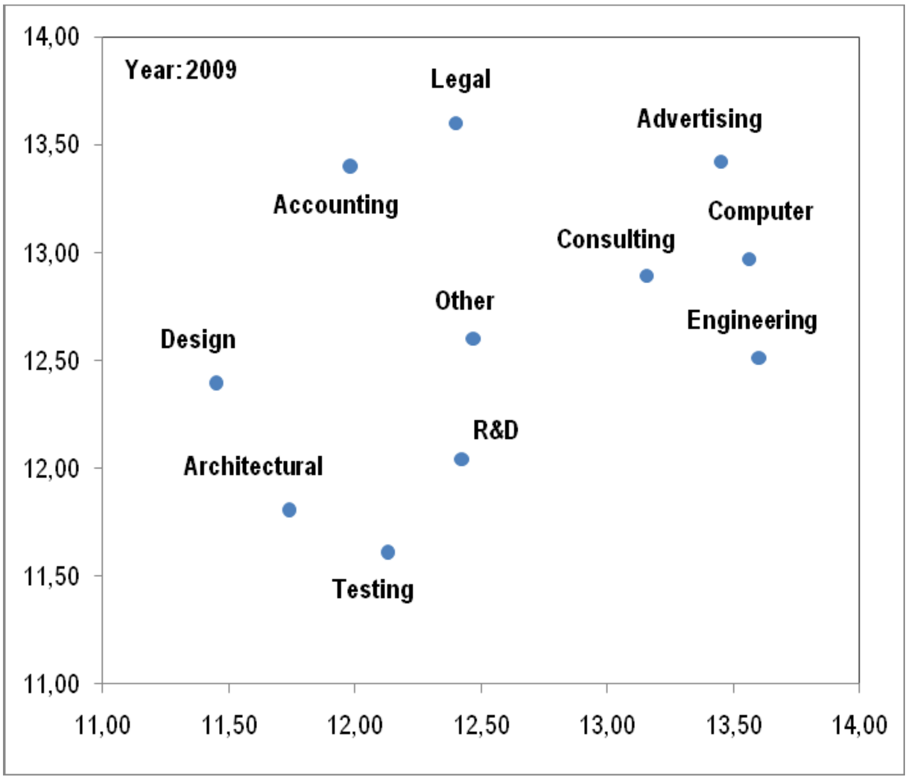

Figure 1c: Distribution of Sectors in factor space, year 2009
(Average Factor 1 in horizontal axis; Average Factor 2 in vertical axis)

		2000			2005			2009		
		B	*S.E.*	*Exp(B)*	*B*	*S.E.*	*Exp(B)*	*B*	*S.E.*	*Exp(B)*
Accounting	COGN_NR	-0.034	0.143	0.966	-0.175	0.203	0.839	0.073	0.106	1.075
	COGN_R	-0.002	0.137	0.998	0.163	0.125	1.177	0.189*	0.110	1.208
Advertising	COGN_NR	-0.208	0.141	0.812	-0.709**	0.341	0.492	0.310***	0.112	1.364
	COGN_R	0.123	0.137	1.131	-0.175	0.189	0.840	0.088	0.114	1.092
Architectural	COGN_NR	-0.420***	0.132	0.657	0.084	0.121	1.088	-0.358***	0.105	0.699
	COGN_R	0.216*	0.129	1.241	0.059	0.113	1.061	-0.717***	0.110	0.488
Computer	COGN_NR	-0.068	0.133	0.934	0.205*	0.116	1.228	0.253**	0.106	1.288
	COGN_R	0.266**	0.129	1.305	0.091	0.114	1.095	0.145	0.108	1.156
Consulting	COGN_NR	-0.259**	0.123	0.772	-0.054	0.142	0.947	0.200**	0.093	1.222
	COGN_R	0.157	0.119	1.170	0.032	0.118	1.033	0.039	0.096	1.039
Design	COGN_NR	-0.203	0.129	0.816	-1.421***	0.523	0.241	-0.023	0.114	0.977
	COGN_R	0.492***	0.126	1.635	-0.774**	0.302	0.461	-0.302**	0.118	0.739
Engineering	COGN_NR	-			0.076	0.125	1.079	0.406***	0.104	1.501
	COGN_R	-			0.042	0.118	1.043	-0.209**	0.104	0.812
Legal	COGN_NR	0.163	0.163	1.177	-0.122	0.194	0.885	0.027	0.114	1.027
	COGN_R	0.143	0.155	1.154	0.304***	0.115	1.355	0.520***	0.123	1.682
R&D	COGN_NR	-0.446***	0.128	0.640	-0.367*	0.192	0.693	0.091	0.095	1.095
	COGN_R	0.065	0.124	1.067	0.095	0.117	1.099	-0.182*	0.098	0.834
Testing	COGN_NR	-			-0.475*	0.265	0.622	-0.067	0.112	0.935
	COGN_R	-			-0.651**	0.254	0.522	-0.389***	0.115	0.678
Ref. Other Professional Services										
Observations		1574			1897			2055		
Model Fitting (Chi-sq)		74.680***			93.226***			223.152***		
Goodness of Fit (Chi-sq)		12386			18742			20025.03		
Likelihood Ratio (Chi-sq)	COGN_NR	42.343***			57.816***			74.365***		
	COGN_R	32.828***			40.161***			156.986***		
% Correct		65.8			78.4			81.6		
Pseudo R-sq (Nagelkerke)		0.047			0.0483			0.103		

Significance levels: *** 0.01; ** 0.05; * 0.10

Table 3: Multinomial Logit

Appendix A

O*NET, the Occupational Information Network, is a database of worker attributes and job characteristics maintained by the U.S. Department of Labor (DOL) and the National Center for O*NET Development, through its contractor Research Triangle Institute. It is the replacement for the Dictionary of Occupational Titles (DOT) and the primary source of occupational information for the US labour market. Data Collection is carried out in two steps: (1) identification of a random sample of businesses expected to employ workers in the targeted occupations, and (2) selection of a random sample of workers in those occupations within those businesses. New data are collected by means of a survey circulated among job incumbents (National Research Council, 2010). Occupations in O*NET are defined according to the criteria of the Standard Occupational Classification (SOC) system. Data Collection provides descriptive ratings based on the questionnaire covering various aspects of the occupation: Worker Characteristics, Worker Requirements, Experience Requirements, Occupation Requirements, Occupational Characteristics, and Occupation-Specific Information. In addition to the questionnaires completed by workers and occupation experts, additional ratings are provided by occupation analysts. Responses from all three sources – workers, occupation experts, and occupation analysts – are used to provide complete information for each occupation. The standardized skill set on which the questionnaire is built contains the categories reported in the table below.

I. Basic Skills	**IV. Social Skills**
Active Learning	Coordination
Active Listening	Instructing
Critical Thinking	Negotiation
Learning Strategies	Persuasion
Mathematics	Service Orientation
Monitoring	Social Perceptiveness
Reading Comprehension	
Science	**V. Systems Skills**
Speaking	Judgment and Decision Making
Writing	Systems Analysis
	Systems Evaluation
II. Complex Problem Solving Skills	
Complex Problem Solving	**VI. Technical Skills**
	Equipment Maintenance
III. Resource Management Skills	Equipment Selection
Management of Financial Resources	Installation
Management of Material Resources	Operation and Control
Management of Personnel Resources	Operation Monitoring
Time Management	Operations Analysis
	Programming
	Quality Control Analysis
	Repairing
	Troubleshooting
	Technology Design

O*NET Standardized Skill set

Appendix B

NAICS Code	Sectors
541100	Legal Services
541200	Accounting, Tax Preparation, Bookkeeping, and Payroll Services
541300	Architectural, Engineering, and Related Services
541330	Engineering Services
541380	Testing Laboratories
541400	Specialized Design Services
541500	Computer Systems Design and Related Services
541600	Management, Scientific, and Technical Consulting Services
541700	Scientific Research and Development Services
541800	Advertising, Public Relations, and Related Services
541900	Other Professional, Scientific, and Technical Services