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# An analysis of the knowledge base of Scientific Research & Development Business Services

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Abstract

It is argued that the literature on SR&D outsourcing focuses mostly on client firms, that is, the demand side, while little is known of the characteristics of the supplying sector. The present paper tackles this gap by elaborating an exploratory analysis of this business service sector with a view to analyse the main patterns of specialization and their evolution over time. Using data on job content and skill requirements in the United States we elaborate a knowledge taxonomy of the sector, and explore how different forms of knowledge co-exist and co-evolve.

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## 1. Introduction

The outsourcing of Scientific and Research & Development (SR&D) is a common business practice whereby a client firm contracts a specialized supplier for the provision of services such as laboratory testing, technology consulting, industrial design or industrial engineering (Chiesa et al, 2004). These suppliers are typically private contract research and technology firms or non-profit hybrid organizations (Howells, 1999). SR&D outsourcing is but one of several instantiations of external knowledge sourcing, a phenomenon that has grown substantially over the last decades and that is both a source of opportunities and of challenges. On the one hand, uncertainty concerning the expected outcomes of research activities and the quality of the knowledge that is to be traded limits the specificity of ex-ante contractual agreements (Howells, 2006). On the other hand, while SR&D outsourcing opens up new avenues, like for example strategic diversification, prolonged resort to it likely undermines the established competence bases of client firms (Ford and Farmer, 1986; Welch and Nayak, 1992). Indeed as contracting of external SR&D has evolved from ‘pure market’ to more hybrid forms of transaction (see Howells et al, 2008) user-producer interactions acquired a relational style that require social and interactive competences at least as much as traditional technical and scientific ones (von

Zedtwitz et al, 2004).

A review of the literature reveals that while a lot has been written about the sources and the effects of SR&D outsourcing from the viewpoint of client firms, that is, of the demand side, the characteristics of the supplying sector are still relatively unknown. The present paper tackles this gap by elaborating an exploratory analysis of the Scientific Research and Development Service sector (NAICS 5417) in the United States with a view to understand: (i) What patterns of specialization can be observed within it? And, (ii) how do these patterns change over time? The availability of data on the job content and skill requirements of individual occupations affords the opportunity to elaborate a knowledge taxonomy of the sector, and to explore how different forms of knowledge co-exist and co-evolve.

The paper is organized as follows. After the conceptual background of Section 2, data are presented and analysed in Section 3. Conclusions summarize.

## 2. Background

This section reviews the main literature on Scientific Research and Development Services. The first part presents the conceptual background while the second analyzes the sector by looking at employment structures and the associated skill bases.

### *2.1 – Scientific Research and Development Services*

The Scientific Research and Development Services sector (NAICS 5417) is made up of firms specialized in the supply of professional, scientific, and technical activities catering for clients both in manufacturing and non-manufacturing industries.[1] Such specialized suppliers are generally modest in size (fewer than 5000 employees), offer services such as laboratory testing, technology consulting, industrial design or industrial engineering (Chiesa et al, 2004), and their expertise covers areas like biotechnology, genetic bioscience, drug discovery and pharmaceutical testing (National Science Foundation, 2005). These businesses proliferate due to the increasing resort to external knowledge sources as strategic vehicles for accomplishing innovation (Amable and Palombarini, 1998; Antonelli, 2006;

1 The finer sectoral classification includes two main subgroups by area of specialization: physics, engineering and life sciences (NAICS 54711) and social science and humanities (NAICS 54712).

Jankowski, 2001; Howells, 1999; Pilat, 2001; Arora et al., 2001; Quinn, 2000). To illustrate, the percentage of R&D activities contracted out by manufacturing companies in the United States has expanded steadily since the early 1990s (Figure 1) until the trend reversal in 2008.

FIGURE ONE ABOUT HERE

From another perspective, the existence of markets for SR&D services is testimony to the broadening of governance mechanisms for the generation, codification and communication of increasingly complex technological knowledge. Professional Services Sectors are a market-based response to the need of interfacing skill-intensive generic knowledge with a variety of specific and idiosyncratic applications (Antonelli, 2006). In the realm of Professional Services, SR&D Business Services falls in the category of 'semantically-rich domains' (Simon, 1969; Consoli and Elche, 2010; 2013), that is, of activities characterized by high degrees of task specificity.[2] Knowledge-intensive services like SR&D modify information content and create new knowledge, and differing from other professional services whose core activity is the mere creation and maintenance of infrastructures for information transmission (Consoli and Elche, 2013). Transliterating Rittel and Webber (1973) SR&D professionals strive with 'wicked' problems, that is problems for which goal formulation is inherently imperfect, and whose nature is not fully understood until a solution has been at least tried. Given this ex-ante indeterminateness, tackling wicked problems entails the exploration and implementation of novel, and often unique, routines. Moreover, as is certainly the case in SR&D, high task specificity limits the replicability of learned solutions across contexts (Carter, 1989; Howells, 1996).

The rationale for contracting out SR&D is widely debated in the literature. These services once portrayed as "formal, routine, repetitive, and cost based with short time horizons" (Andersen et al., 2000) have now evolved into long-term commitments wherein specialized suppliers are closely involved in their clients' strategy design while at the same time carrying out core research activities (Howells, 2000). The market for SR&D outsourcing covers a broad knowledge spectrum, especially for companies operating in high technology sectors. By tapping on specialized

2 Other semantically-rich professional service sectors are: Architectural, Engineering and related services (NAICS 541300), Computer System Design (NAICS 541500) and Management, scientific, and technical consulting services (NAICS 541600). See Consoli and Elche (2013).

competences, client firms seek to reduce risks and focus internal SR&D on activities that are closer to their core business (Martínez-Noya and García-Canal, 2011). The increasingly complex and multidisciplinary nature of innovation coupled with advances in information and communication technologies has encouraged the partitioning of SR&D activities into components holding different strategic importance in relation to technology and product life-cycles (Gottfredson et al., 2005, Pavitt, 1999). In addition, the scope and organization of SR&D has been observed to evolve and diversify fast as a consequence of various developments in corporate strategy (Hsuan and Mahnke, 2011; Lewin and Peeters, 2006; UNCTAD, 2005). First, there is increasing awareness that innovation and knowledge critical to SR&D is created more efficiently outside corporate boundaries (von Hippel, 2005; Howells et al., 2008). Secondly, it has been shown that many sectors deal with decreasing SR&D productivity by encouraging higher modularization and off-shoring (Mahnke, 2001; Mikkola, 2006; Chesbrough and Appleyard, 2007). Third, companies outsource not only in pursuit of higher efficiency but also to explore new opportunities through the capabilities of specialized suppliers (Graf and Mudambi, 2005). The expected benefits of SR&D outsourcing at firm level (e.g., access to global talent, tapping into foreign knowledge sources, and accelerated product development) are widely documented (Quinn, 2000; Chesbrough, 2006; Gassmann et al, 2010).

We argue that the existing literature on SR&D outsourcing yields an unbalanced view: while the strategic aspects of the demand by client firms have been covered in detail, very little is known about the supply side (Chiesa et al, 2004; 2008). The remainder of the paper explores this new territory by addressing two questions: i) What kind of knowledge is involved in the provision of these specialized services? And, ii) how has the knowledge base evolved? To meet these goals, we elaborate an empirical analysis of the employment structure and the skills base of the SR&D Business Services sector. Before detailing the specifics of this exercise, it is appropriate to spell out the conceptual reasons behind this particular focus.

### *2.2 – Employment and skills: fingerprints of knowledge application*

We are not alone in highlighting the relevance of employment structures and skills in management and economics. Barley and Kunda (2001) and Malhotra and Morris

(2009) acknowledge the significant contributions from sociology (e.g. Abbott 1988; Collins 1990) on the role of professions in knowledge production and lament the scarce attention from management scholars. Similar concerns can be heard in innovation studies where division of labour and adaptations of employment structures are perceived as important but, again, understudied aspects of technology diffusion (Freeman and Soete, 1987; Caroli, 2001). Other scholars graft the relationship between innovation and employment on the dynamics of institutions that enable knowledge systematization (Rosenberg, 1976) and the regeneration of skills' life-cycles (Vona and Consoli, 2011). Macro-level studies in economics also unravel the complicated relationship between technical change and movements in productivity growth by considering cycles of skill emergence and obsolescence (Acemoglu et al. 2006; Goldin and Katz 2008). A handful of recent empirical studies further enrich our understanding of skill heterogeneity in a variety of contexts (see e.g. Lavoie and Therrien, 2005; Neffke and Henning, 2009; Giuri et al., 2010).

In the present paper employment structures and their underpinning knowledge bases are viewed as useful entry points to understand what a sector is about. According to Malerba (2005) the development of a sector is punctuated by the co-evolution of three component dimensions: the knowledge base; networks of actors; and the underpinning institutional infrastructure. With regards to the knowledge base, ample literature supports the notion that professionalization is an important institutional mechanism for matching bits of useful knowledge (or skills) to the demands of an occupation (or tasks) (Autor et al, 2003; Levy and Murnane, 2004). In turn, the systematization and codification of knowledge into usable instructions are key prerequisites for professionalization (Rosenberg, 1976; Cowan et al, 2000). As a matter of fact, the two processes are complementary to the extent that professionalization acts as variation mechanism by spurring novel routines while systematization is a selection filter for newly codified knowledge before this is transmitted and adapted to various contexts of use.

In aggregate, the composition of the workforce reflects the knowledge mix that is relevant in a particular sector at a specific moment. This implies that the complementarities across different forms of knowledge matter a great deal for the ability of an individual worker to meet successfully their job requirements depends on the composition of the overall employment structure and on mechanisms of intra-occupations collaboration. The emergence of novel configurations in the skill mix reflects changing styles of framing and addressing job tasks by redistributing responsibilities across professional groups. The occupational structures and the kind of skills that are relevant in a sector at any point in time are engaged in an open-ended chase along the trajectory of knowledge growth. In this framework the evolutionary process of knowledge exploration, recombination and coordination entails alterations in the skill mix, by either modification of the existing configurations of the creation of new combinations (Nelson and Winter, 1982; Metcalfe, 2002).[3]

Building on this conceptual ground, the present study seeks to explore the knowledge base of the SR&D sector by looking at the repertoire of skills underpinning the attendant occupational structure. The availability of data on the job content and skill requirements of individual occupations (detailed in the following section) offers a good entry point to elaborate a knowledge taxonomy of the sector by exploring how different forms of knowledge co-exist and how they evolve.

## 3. Empirical analysis

### *3.1 – Data*

Our empirical analysis is based on the Occupational Information Network (O*NET) electronic database of the U.S. Department of Labour (DOL). Data are collected using a classification system that organizes job titles into 1,102 occupations and collects information on their characteristics. Information on the abilities and skills domains is occupation-specific and is provided by trained occupational analysts, job incumbents and labour market experts who assign a score to 36 types of skills (see Appendix A) on the basis of the perceived importance for task performance. The current taxonomy encompasses information on two broad categories, basic and cross-functional skills. For what concerns the former, skills are further separated into “content” (e.g. reading, writing and listening) and “process” skills aimed at cognitive information processing

3 The obvious reference here is to the cake metaphor that is quite common among evolutionary economists as explained in Nelson et al (1967: 99): “Generally, a technique or technology is not describable by a unique routine; usually there are options in the program. These options permit some choice of inputs and input proportions (a recipe may work with either whole or powdered eggs) and some flexibility with respect to operations (the eggs may be added before or after the sugar). The operations may be performed in different ways; for example, different degrees of mechanization may be employed (the mix may be beaten with a spoon, a hand beater or an electric beater). Some variation in output specification may be possible (such as the shape of the cake or the kind of frosting)”.

activities. Cross-functional skills are organized in five categories: problem-solving skills, technical skills, social skills, systems skills, and resource management skills.

The O*NET classification uses the Standard Occupational Classification (SOC) system and is therefore aligned with other sources of occupational information such as the Bureau of Labor Statistics (BLS). Our database was built by merging employment statistics on Professional, Scientific, and Technical Services (NAICS 54) with the corresponding occupational information on skills contained in O*NET. The observations available to us are occupational categories for which we have information on total employment (source: BLS), a vector of skill intensity scores and the average number of years in excess of High-School (Standard Vocational Preparation) (source: both from O*NET). The sample used here includes information on the 300 occupational titles over the period 2002-2010.

*3.2 – Analysis*

The analysis is divided in various steps. First, a descriptive analysis of employment structure in the SR&D Service Sector is presented. Subsequently, we employ factor analysis to extract the main skill groups and discriminant analysis to explore the macro-correspondences between occupations and skills. An appreciation of the longitudinal behaviour of the skill base concludes the section.

Let us examine first the occupational structure of the sector between 2002 and 2010. As shown in Figure 2 total employment (bars, right-hand side axis) increased steadily through most of the period except for the decline of the last two tears. A closer look at the breakdown by occupational categories (lines, left-hand side axis) indicates that Scientists hold the highest occupational share (average 23%) followed at a distance by a block of four occupations: Office and Administrative Support workers, slightly declining (down to 11% share in 2010 from the initial 20%), Architectures and Engineers (10% to 16%), Computer and Mathematical Science (10% to 13%) and Managerial occupations (10% to 15%). Still further below are Business and Finance workers (8% to 12%) and sixteen more occupations (see full list in Appendix A) whose aggregate share is below 18% throughout the period. The occupational composition of the R&D Service sector is therefore strongly polarized into two blocks, scientists on the one hand and a mix of professionals (e.g. Engineers) and lower white collar workers (e.g. Office and Administrative support).

FIGURE TWO ABOUT HERE

Turning to the skill structure underpinning this configuration of the labour force, each occupation is associated to a vector of 36 skills. Principal Component Analysis (Hotelling, 1933) allows us to reduce variables and extract four skill components (Table 1). The first includes a mix of interactive (e.g. Social Perceptiveness, Persuasion, Coordination), organizational (e.g. Time Management) and cognitive (e.g. Decision Making, Critical Thinking) skills. We label this group "Cognitive-Interactive". In the second component are cognitive skills aimed at content (e.g. Mathematics, Science), processes (e.g. Complex Problem Solving, Active Learning) and objects (e.g. Programming), and we label it "Cognitive-Analytical". The third component includes manual skills (e.g. Installing, Repairing, Maintenance) and 'narrow' (e.g. aimed at routine operations) cognitive skills such as Operation Control, Operation Monitoring and is labelled as "Technical". The last component comprises "Administrative" skills. Summing up this first exercise, and drawing from previous literature (Autor et al, 2003; Levy and Murnane, 2004) we distinguish between two meta-components: cognitive non-routine skills (Factors 1 and 2 – interactive and analytical) and routine skills (Factors 3 and 4 – Technical and Administrative skills).

TABLE ONE ABOUT HERE

In the conceptual framework outlined above occupations are understood as instituted channels for the implementation of skills to meet specific goals. It is interesting to substantiate this idea by looking at the match between groups of skills and of occupations. Discriminant analysis yields the configuration of Table 2. Here we appreciate that *Technical skills* factor is the strongest discriminant for the following group of occupations: Installation, maintenance and repair; Production; Construction; Farming, fishing and forestry; Office and administration support; Health support; Transport, etc. The group that is associated to *Interactive skills* includes Community and Social Service workers; Legal workers; Education and training; Sales; Arts and Design; Protective Service; Personal Care and Service Workers. In the third group *Analytical skills* is the discriminant for Computer and Mathematics Professionals;

Architect and Engineers; Scientists; Health practitioner. The smallest group of occupations includes Management and Business and Financial Services professionals.

TABLE TWO ABOUT HERE

We find useful reference in previous literature on the classification of worker types to interpret the above skill-occupation correspondences. According to Nelson (1988) and Wymbs (2012), *finders* are professional experts whose job involves intensive use of cognitive abilities. Our analysis detects two sub-groups of Finders in SR&D, namely "interactive spanners" and "scientific spanners". The former include occupations with a strong relational component mostly defined by interactive skills like, for example, Legal, Protective Service and Education workers (Group 1). The scientific spanners instead are professionals such as Architects and Engineers, Health practitioner or Scientists, using intensively cognitive skills and, at the same time, engaging close-to-the-frontier analytical activities. The second major group of workers mentioned in the cited literature are *Grinders*, often referred to as fungible workers with basic knowledge and carrying out routine manual activities. In the discriminant analysis above these are the low-skilled workers. Finally *Minders*, professionals engaging largely routine tasks and usually operate within a team, match the composition of Group 4, with Managerial and Business and Financial workers.

At this point it is intriguing to look at the dynamics of the skill mix, and more specifically at the changing intensities of the four skill factors during the period 2002-2010.[4] The diagram of Figure 3 shows that Cognitive skills, both Interactive and Analytical, have relative higher intensity. Moreover, despite starting at similar levels, Interactive skills grow faster than Management skills and eventually catch up with Cognitive Analytical skills towards the end of decade. Conversely, the Technical skills component scores low throughout the period.

FIGURE THREE ABOUT HERE

If on the one hand the prominence of Cognitive skills is somewhat to be expected in the remit of knowledge-intensive activities, the growing importance of cognitive-interactive skills resonates with the earlier remark apropos of client-supplier interactions stimulating the broadening of competence bases (von Zedtwitz et al,

[4] Skill intensity is calculated by mean of the O*NET score for each skill weighted by employment and average formal education per profession. See Consoli and Elche 2010 for more details.

2004). Yet another noteworthy outcome is the overall low magnitude of technical skills, which stands in contrast with previous literature on the importance of low-skilled technical workers in R&D (see e.g. OEDC, 2009; Turpin et al, 2011; Toner et al, 2010). An important difference, to which we attribute this incongruity, is that the cited studies use data on internal R&D performed by firms across all sectors while our focus in solely on the professional SR&D business service sector.

Behind the foregoing aggregate movements, we argue, lie interesting changes. The knowledge base of a sector can be thought of as a portfolio of skill combinations that is adapted over time to the broader competitive circumstances through the composition of the labour force. In the framework presented here skill combinations are co-occurrences, that is, the joint utilization of two particular skills by one profession. The frequency of these co-occurrences is interpreted as a measure of the strength of the association between skill couples. The formation, dissolution or changes in intensity of skill dyads reflect alterations in the employment structure typically in the form of modifications in the job content, the creation of new occupations, or both (Autor et al, 2003). Building on previous literature (Nesta and Saviotti, 2005; Frenken et al, 2007; Saviotti and Frenken, 2008; Krafft et al, 2011) we compute a *Total Variety* index, that is, the weighted sum of the probabilities that two skills co-occur within the same occupation. This is a multidimensional measure of the variety of skill dyads in the labour force of the SR&D Service sector. Since information on skills co-occurrences are available at different levels of aggregation, 2-digit and 5-digit occupational categories, we can break down the Variety index into *Within* and *Between* components. Taking skill dyads as indicators of knowledge variety, the Within (or Related) component captures changes in intensity of existing skill combinations; conversely, Between (or Unrelated) Variety is a measure of the replenishment of knowledge combinations, either new skill co-occurrence or the decline of existing ones. Summing up the former can be interpreted as *adaptive* changes in the knowledge base aimed at fine-tuning the 'use' of a particular combination of skills via changes in existing occupations; the latter are *transformative* changes occurring as a result of job contents being modified or new occupations, and new skill combinations, emerging.

FIGURE FOUR ABOUT HERE

The diagram in Figure 4 shows the movements of the three variety indexes. Here we observe that Total Variety and Unrelated (Within) Variety follow a broadly similar trend, steady increase until the trend reversal in 2008.[5] Interestingly, Unrelated Variety is much lower than Related Variety early in the decade but catches up fast in 2005. After a short spell in which Unrelated Variety is higher than Related Variety, over the last three years the latter grows sluggishly while the former declines rapidly. Given the similarity of patterns between Unrelated and Total Variety, Related Variety appears to act as a mitigating factor: hampering the ascent of TV when new knowledge combinations grow rapidly at the beginning of the period, and smoothing the decline when the trend of UV reverses. Such is, we argue, the effect of inertia in decoupling knowledge combinations.

But the broader goal of this last part of the analysis is to show that behind aggregate structure stands a rich fabric of combinatorial possibilities. This leads us to appreciate that at the beginning of the decade the knowledge base went through a dynamic phase wherein new combinations of skills were spurred by either changes in job content or new occupations. In the last part of the decade Related and Unrelated Variety diverge with the latter falling faster than the former, likely due to the combination of slowdown in employment growth and, possibly, the exhaustion of combinatorial possibilities after the fast growth in the first decade. Put another way, this is an indication that the knowledge base of the sector experience some degree of inertia.

## Concluding remarks and the way ahead

This is an exploratory study on the knowledge base of SR&D Professional Services spurred by the observation that, in spite of the widely acclaimed relevance, there is a gap in the knowledge of the characteristics of this sector. Against this paucity of research, besides sparse case study material and anecdotic evidence from gray literature, our analysis makes a first step in uncovering the rich knowledge structure underpinning the organization of the sector. We derived useful indications by looking at the composition of the labour force and the underpinning sets of skills that define professions in SR&D business services. Rooted in an arguably unexplored conceptual

[5] Between Variety is calculated as the entropy of the 2-digit (Standard Occupational Classification: SOC) occupations (e.g. Management Occupations, Legal Occupations, etc) while Within Variety is the weighted sum of the entropy at the five-digit level within each two-digit occupation class (e.g. Chief Executives, General and Operations Managers et cetera within Management Occupations).

ground at the interface of management, economics and sociology, the empirical exercise proposed here offers a preview at what can be learned on the knowledge fabric of a sector once employment and skills are accounted for.

In the particular case at hand, our study confirms that the SR&D services sector resembles other high-level, semantically-rich, Professional Services in which intensive interaction with clients, project-driven activities and strong interdependencies across occupations are crucial to the business. In so doing it also restates the marked diversity that exists across Professional Service Sectors as a whole. Preliminary as this analysis may be, the prominence of cognitive non-analytical skills resonates with previous works suggesting that the core of SR&D is shifting towards a 'relational' transaction style where creative and interactive skills are increasingly necessary. And the contrast with the negligible intensity of technical skills may well provide yet further support to that argument.

Following these initial steps, we foresee various promising directions for further developments in this area. At a similar level of aggregation, the sector, much can be learned by exploring covariates of changes in occupations and skills – the typical candidates for this type of exercise being i.e. Gross Value Added or investments in office, computing, and scientific equipment. Furthermore, evidence from countries other than the US would open up interesting avenues to appreciate the role of local labour markets in enabling or hampering sectoral development. But there is ample scope for analysis at lower levels of aggregation. The still scant evidence on skills in SR&D outsourcing suggests that professional service suppliers are beginning to realize and address skill gaps, especially social and interactive skills that can hardly be learned in formal training programs. Add to this that professional service workers are increasingly required to maintain relations not only with clients but also with co-workers. This is important in relation to the challenge of nurturing the problem-solving capabilities of creative workers by creating intra and inter-firm teams. It is hoped that dedicated firm-level studies will address these issues to gain better understanding of particular business service sector as well as of the changes in the rationale and the organization of Scientific Research and Development outsourcing.

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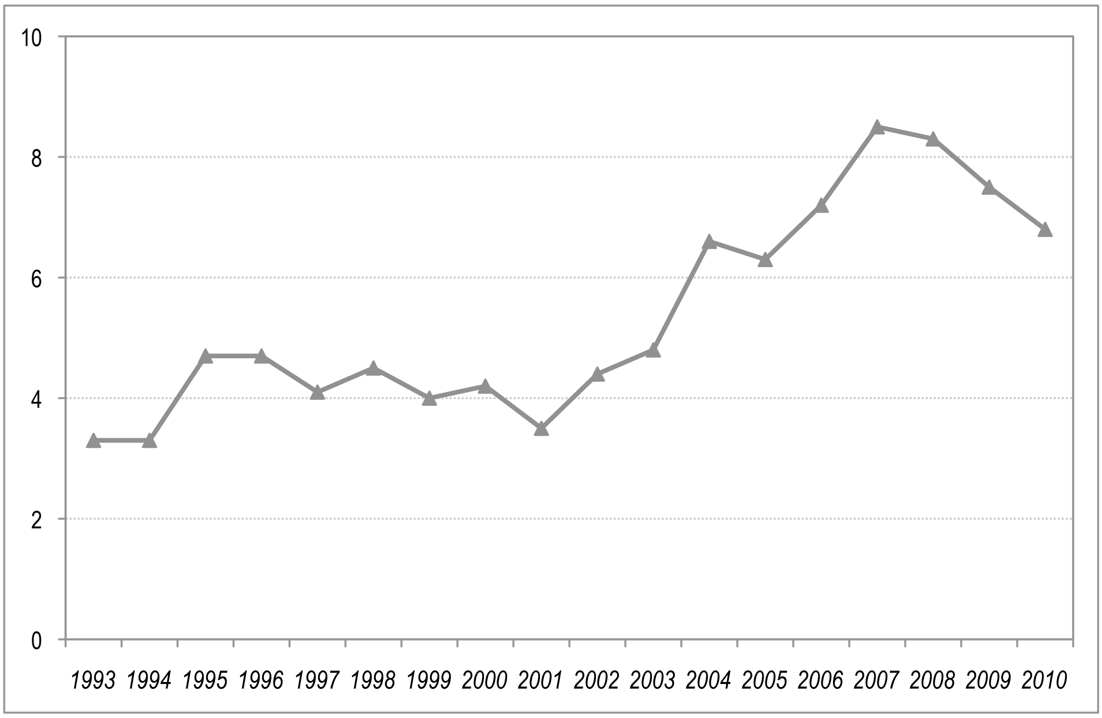


**Figure 1: % R&D contracted out in United States by manufacturing companies as ratio of company-funded and -performed R&D: 1993–2010**

(SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development. Science and Engineering Indicators – various years)

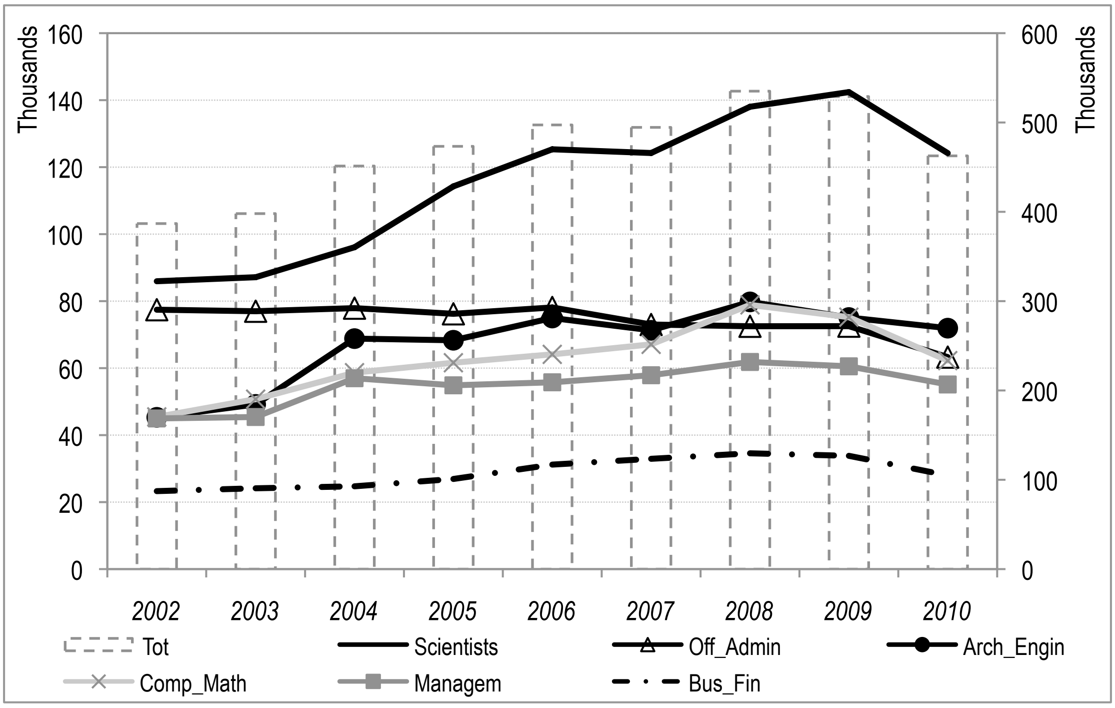


**Figure 2: Breakdown of Total Employment in SR&D Business Services, 2002-2010**

**Table 1. Factor analysis**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Social Perceptiveness | **0.899** | -0.049 | -0.157 | 0.137 |
| Active Listening | **0.875** | 0.303 | -0.073 | 0.082 |
| Service Orientation | **0.85** | -0.165 | 0.011 | 0.084 |
| Time Management | **0.839** | 0.188 | 0.085 | 0.297 |
| Instructing | **0.833** | 0.187 | 0.194 | 0.027 |
| Learning | **0.828** | 0.328 | 0.147 | 0.042 |
| Speaking | **0.815** | 0.337 | -0.227 | 0.18 |
| Persuasion | **0.811** | 0.162 | -0.042 | 0.327 |
| Negotiation | **0.771** | 0.066 | -0.052 | 0.436 |
| Monitoring | **0.758** | 0.316 | 0.035 | 0.374 |
| Coordination | **0.752** | 0.183 | 0.173 | 0.441 |
| Critical Thinking | **0.664** | 0.652 | -0.009 | 0.196 |
| Writing | **0.64** | 0.574 | -0.257 | 0.115 |
| Decision Making | **0.589** | 0.516 | 0.002 | 0.483 |
| Mathematics | 0.12 | **0.793** | 0.129 | 0.17 |
| Science | 0.136 | **0.78** | 0.184 | -0.032 |
| Complex Probl-Solving | 0.513 | **0.714** | 0.091 | 0.315 |
| Programming | 0.013 | **0.686** | 0.183 | 0.104 |
| Active Learning | 0.657 | **0.677** | 0.079 | 0.132 |
| Reading | 0.647 | **0.669** | -0.081 | 0.043 |
| Operation Analysis | 0.24 | **0.663** | 0.265 | 0.426 |
| Equipment Maintenance | -0.014 | -0.112 | **0.93** | -0.053 |
| Repairing | -0.058 | -0.082 | **0.897** | -0.023 |
| Troubleshooting | 0.135 | 0.298 | **0.867** | 0.085 |
| Installing | 0.004 | 0.138 | **0.851** | 0.053 |
| Operation Control | -0.157 | -0.013 | **0.832** | 0.012 |
| Operation Monitoring | -0.104 | 0.097 | **0.802** | 0.042 |
| Equipment Selection | 0.147 | 0.388 | **0.748** | 0.101 |
| Quality Control | 0.059 | 0.469 | **0.653** | 0.191 |
| Technology Design | 0.133 | 0.582 | **0.592** | 0.165 |
| Managem of Materials | 0.322 | 0.168 | 0.295 | **0.713** |
| Managem Financial Res | 0.484 | 0.155 | -0.057 | **0.693** |
| Managem of Personnel | 0.546 | 0.075 | -0.019 | **0.689** |
| System Evaluation | 0.222 | 0.553 | 0.067 | **0.642** |
| System Analysis | 0.138 | 0.599 | 0.11 | **0.607** |
| % of var. explained | 46.069 | 19.337 | 8.281 | 4.770 |
| Cumulative % expl. | 46.069 | 65.407 | 73.688 | 78.458 |

Exploratory factor analysis with principal components as the initial factor method

Rotation method: orthogonal Varimax with Kaiser normalization.

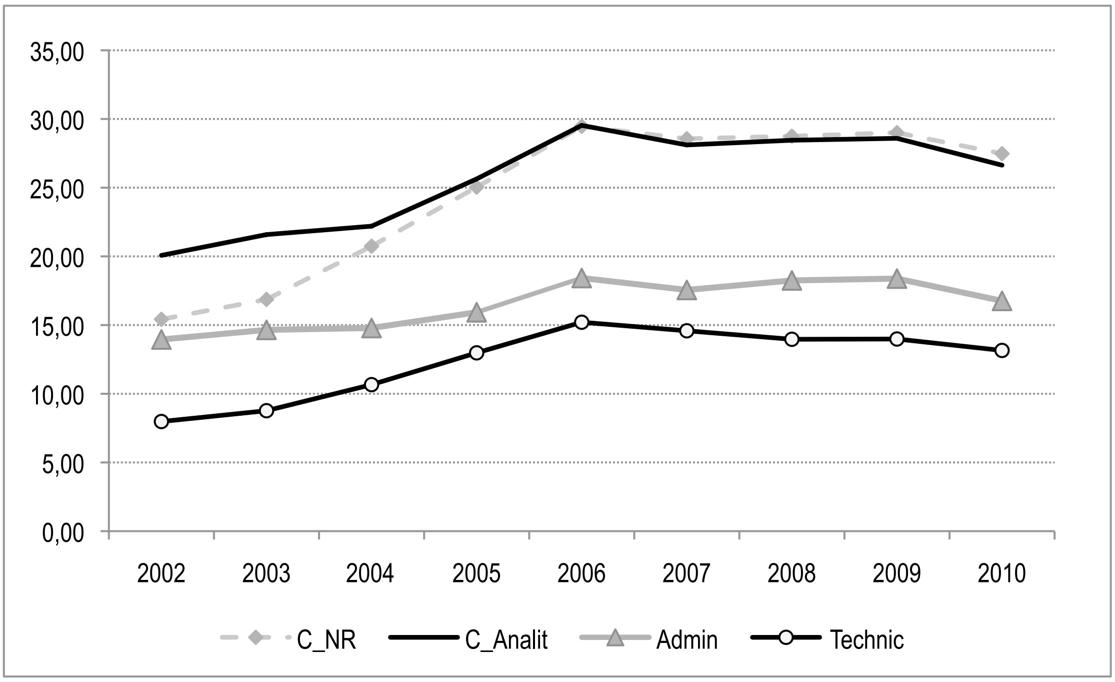


**Figure 3: Skill Factors, 2002-2010**

| *2-digit Occupational Groups* | *Interactive* | *Analytical* | *Technical* | *Administrative* |
|---|---|---|---|---|
| Community and social service | 28.358 | | | |
| Legal | 21.512 | | | |
| Education & training | 18.165 | | | |
| Sales | 6.231 | | | |
| Arts, design & media | 5.798 | | | |
| Protective service | 5.026 | | | |
| Personal care and service | 4.686 | | | |
| Computer and Mathematics | | 44.258 | | |
| Architects & Engineers | | 26.490 | | |
| Scientists | | 25.603 | | |
| Health practitioners | | 2.396 | | |
| Install, maintenance & repair | | | 43.360 | |
| Production | | | 28.351 | |
| Construct & extract | | | 18.760 | |
| Farm, fish & forest | | | 18.389 | |
| Food & serving | | | 1.822 | |
| Office and admin support | | | 10.620 | |
| Transport and material | | | 10.619 | |
| Building & maintenance | | | 5.639 | |
| Health support | | | 2.238 | |
| Management | | | | 27.960 |
| Business and financial | | | | 10.567 |

| **Wilks' Lambda test (Rao's approximation):** | |
|---|---|
| Lambda | 0,08 |
| F (Observed value) | 101,42 |
| F (Critical value) | 1,27 |
| DF1 | 84 |
| DF2 | 9573,08 |
| p-value | < 0.0001 |
| alpha | 0,05 |

*Test interpretation*

H0: The means vectors of the 22 classes (Occupations) are equal.

Ha: At least one of the means vector is different from the others

As the computed p-value is lower than 0.05, one should reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

**Table 2: Discriminant Analysis Occupations-Skills**

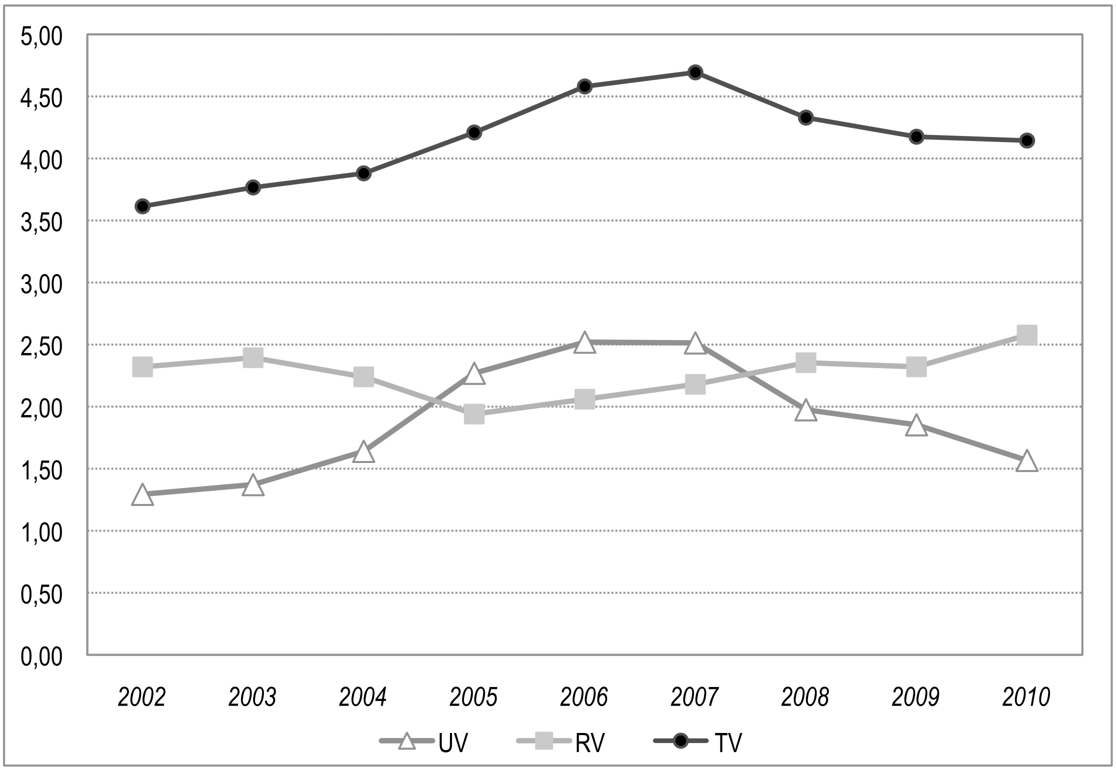


**Figure 4: Total Variety (TV), Unrelated Variety (UV) and Related Variety (RV), 2002-2010**