Technological learning environments and organizational practices. Cross sectoral evidence from Britain

Isabel Maria Bodas Freitas

Cite as: "Bodas Freitas, I.M. (2011). Technological learning environments and organizational practices. Cross sectoral evidence from Britain. Industrial and Corporate Change, 20, 1439-1474."

Technological learning environments and organizational practices. Cross sectoral evidence from Britain

Isabel Maria Bodas Freitas

Abstract

This study explores the co-occurrence of technological and organizational learning processes by analysing the adoption and use of four types of Human Resource Management (HRM) practices, rewarding, problem-solving, top-down management and decentralization, in the 1990s, across different technological learning environments. Using a sample of British workplaces, we show that the level of use of diverse HRM practices, aimed at creating different learning incentives, is persistently heterogeneous across technological learning environments, suggesting that HRM forms an essential part of the technological learning structure of firms.

Keywords: organizational learning, human resource management practices, sectoral patterns, innovation adoption

1. Introduction

Management and organizational practices are often understood as the mechanisms used to co-ordinate knowledge, incentives, and communication within a firm, and between a firm and its customers and competitors (Coriat and Dosi, 2002; Dosi *et al*., 2003; Dosi and Marengo, 2007). Management and organizational practices govern the knowledge on technology, markets and organization and, consequently, shape the processes of search and implementation of innovation and technological change (Dosi, 1997; Coombs and Hull, 1998; Cabrales *et al*., 2008). Given their importance for the accumulation of knowledge and innovative capabilities in firms (Coriat and Weinstein, 2002), the pattern and the impact of workplace management practices, especially Human Resource Management (HRM) practices, have been widely studied in the literature

Using different definitions and measures of *high performance or innovative* practices that foster information sharing, teamwork and employee participation, several studies analyse their impact on firm performance. These studies find that the use of these practices enhances productivity, financial performance, technological change and innovativeness and decreases employee turnover (Huselid, 1995; Ichniowski *et al*., 1997; Michie and Sheehan, 1999; Caroli and van Reenen, 2001; Bresnahan *et al*., 2002). Moreover, the combined use of several new HRM practices may allow firms to achieve higher performance, but do not always result in greater employee satisfaction (Whittington *et al*., 1999; Ramsay *et al*., 2000; Massini and Pettigrew, 2003; Macky and Boxall, 2007).

There is some interesting empirical evidence that suggests that the use of innovative HRM practices can differ across firms with diverse characteristics but facing similar challenges (Massini *et al*., 2002; Lepak *et al*., 2007). This evidence provides support for the resource-based view of the firm, and its extensions into the dynamic capability literature. According to this literature, competitive advantage is based on specific firm resources, especially organizational structures and practices that enhance learning and the way firms respond to external technological and market challenges (Penrose 1959; Barney and Wright, 1998; Kor and Mahoney, 2004). While this literature goes into detail about the role of organizational practices on firm performance, there is less discussion about the co-occurrence of technology and organizational learning processes or, consequently, about whether some organizational practices are more likely to be adopted by firms active in particular technological environments. Our study attempts to address this latter issue.

Firms active in different industries rely on diverse technological and market knowledge bases and exploit specific learning processes (Malerba, 1992) and the literature on technological regimes provides evidence of different patterns of knowledge accumulation, learning and technological opportunities across industries (e.g. Malerba and Orsenigo, 1997; Marsili, 2001, 2002; Castellacci, 2008). However, so far, little attention has been paid to the joint occurrence of organizational and technological activities.[1] In this paper, we argue that the use of certain HRM practices can differ substantially across technological environments in which there are different incentives to enhance specific forms of internal learning.

We employ the taxonomies proposed by Pavitt (1984), Marsili (2001) and Miozzo and Soete (2001) to analyse the use of different HRM practices across technological learning environments to try to bridge between the technology and innovation and organizational studies literatures. The analysis provides particular insights into the contribution of HRM practices for the processes of search and knowledge accumulation within firms active in different industrial and technological environments.

Our study focuses on the use of HRM practices in the 1990s, a period characterized by specific management and innovation challenges, and specific organizational responses (Whittington *et al*., 1999; Pettigrew and Fenton, 2000). In the 1990s, firms developed new organizational forms to deal with and benefit from the challenges and opportunities created by the globalization of markets and production and research activity, and the diffusion of

Information and Communication Technologies (ICT) (Pettigrew and Fenton, 2000; Wang and von Tunzelmann, 2000; Ichniowski and Shaw, 2003). Firms revised their organizational learning structures and processes to facilitate their responses to similar learning challenges. Against this background, we analyse the co-occurrence of firms' technological and organizational activities by analysing the heterogeneity in the use of different types of HRM practices exploited to create specific learning incentives in technological learning environments.

We rely on information on British workplaces from the *Workplace Industrial Relations Survey* (WIRS) database.[2] This database allows us to focus on the use of four types of HRM practices: reward, problem-solving, traditional top-down, and decentralizing informational management practices, in various technological learning environments. The analysis also considers how the characteristics of the workplace and the channels of diffusion of managerial information can influence HRM practices. Our results show that the use of HRM practices generally differs across technological learning environments, as identified by the Pavitt-Marsili, and Miozzo-Soete taxonomies. They show also that the organizational, relational and market characteristics of firms may have different effects in terms of HRM practices in industry learning contexts. In this the paper, we argue that HRM is an essential part of the technological learning structure of firms

Our study contributes to the work on technological regimes and the resource-based view of the firm by highlighting the co-occurrence of technological and organizational learning processes, and by providing evidence that certain organizational and HRM practices are more effective in some technological environments compared to others.

The remainder of the paper is organized as follows. Section 2 reviews the literature on the main factors affecting the development and use of *innovative or high-performance* HRM practices. Section 3 discusses the different technological learning environments and our expectations in relation to the use of different HRM practices, and the way they contribute to the creation of diverse learning incentives for the firms in these environments. Section 4 describes the data and the methodology. Section 5 presents the results of the empirical analysis, and discusses the importance of particular HRM practices to support learning and innovation in various industrial and technological contexts. Section 6 concludes.

2. The literature on HRM practices

The relationship between competition and the organizational structures of firms is widely acknowledged in the literature. It has been argued that the emergence of new organizational forms and HRM practices is linked to technological change and the evolution of forms of competition, and institutional changes in the labour market (Hendry and Pettigrew, 1992; Teece, 1996; Coriat and Dosi, 2002; Acemoglu et al., 2007; Bryson *et al.,* 2007).

Several studies see the development and use of new HRM practices in firms as responding to specific external market and technological challenges and also internal conflicts and objectives (Hendry and Pettigrew, 1992; Coriat and Weinstein, 2002; Massini *et al.,* 2002). New HRM practices often coincide with the definition of new market goals and incentive and penalty systems related to particular individual and collective activities (Coriat and Dosi, 2002; Dosi *et al*., 2003). Skilled labour and new organizational practices are seen as complementing technological change, resulting in the introduction of new products and services (Michie and Sheehan, 1999; Caroli and van Reenen, 2001; Bresnahan *et al*., 2002). Hence, the development and use of new practices would seem to be associated with the firm’s need to adapt learning structures.

In the 1990s, in particular, firms established new organizational forms to cope with the new competitive environment characterized by the globalization of markets, production activities and technologies, and by the increased importance of ICT, to improve the performance of all business processes. To respond to and appropriate the benefits of the new technological and market challenges, firms established organizational forms that facilitate collaboration with customers and enhance process efficiency and new product development (Whittington *et al.*, 1999; Pettigrew and Fenton, 2000; Bresnahan *et al.*, 2002; Ichniowski and Shaw, 2003). HRM practices, such as work appraisals, teamworking, and participation in decision-making have become particularly important.

The adoption of new HRM practices may also reflect the need for firms to legitimize managerial choices in their market and social environment, to sustain competition, to avoid penalization and to achieve certain 'expected' outcomes. Network, social and emotive benefits can positively influence the expected financial returns from innovation adoption (Abrahamson and Rosenkopf, 1993). Some argue that when public discourse claims that a performance gap can be addressed by a new management practice; there is the danger that firms adopt a practice independently of its expected performance. The diffusion of some practices would then be driven by the firms' decision to follow the 'fashion' or to jump onto the 'bandwagon' to avoid being penalized for their non-adoption (Abrahamson, 1991; Haunschild and Miner, 1997; Abrahamson and Fairchild, 1999; Nelson *et al.*, 2004).

Business consulting advice would seem to support the dissemination and adoption by firms of new HRM practices (Abrahamson and Rosenkopf, 1993; Huczynski, 1993). Being part of an industry network, such as an industry association, may provide access to information on management best-practice and act as an incentive to adopt it. Managers seem to adopt new HRM practices because they believe they provide the solution to a particular critical problem, and see them as devices that will legitimize and reduce internal conflict emerging as the result of organizational change (Huczynski, 1993; Alvesson and Karreman, 2007).

Despite an apparent horizontal diffusion of HRM practice, led by changes in the competitive and technological environments of firms, by 'fashions', and by the need for managers to legitimise internal changes, the new HRM practices are not widespread across the economies

(Godard and Delaney, 2000; Lepak *et al*., 2007). Their use differs across firms with different characteristics but facing similar challenges, suggesting that the introduction of new HRM practices may be mainly a 'responsive behaviour' motivated by performance considerations, in a specific period of time (Ichniowski and Shaw, 1999; Pettigrew and Fenton, 2000; Massini *et al*., 2002; Lepak *et al*., 2007). HRM practices in firms vary according to such characteristics as size, affiliation to groups, presence of foreign capital and R&D intensity (Kotey and Slade, 2005). Larger firms and firms that belong to a group, facing major organizational challenges to co-ordinate and structure their information-sharing and learning incentives, are more likely to adopt innovative HRM practices (Massini *et al*., 2005; Bryson *et al*., 2007).

The location of the firm's most important market may also provide an incentive for investment in particular learning processes and use of particular HRM practices. Providing a customized product/service, and complying with local and national management styles, may be especially important to maintain competitiveness in local markets, while good quality and good-value products/services may be important for remaining competitive in the international market (Whittington *et al*., 1999; Miozzo and Soete, 2001). Also firms with different product-portfolios and strategies for the development of multi-technology competencies, seem to rely on specific learning processes and, thus, particular organizational strategies and HRM practices (Granstrand *et al*., 1997; Lai *et al*., 2010). HRM practices that enhance spillovers between technologies and products may be crucial for multi-product and multi-technology firms.

While most contributions focus on firm level differences, there are reasons why we can expect the use of HRM practices also to differ across industries. Datta *et al*. (2005) show that industry-level differences in capital intensity, product differentiation and industry growth affect the impact of innovative workplace practices on firm productivity. Greenan (2003) shows that the impact of certain HRM practices on the employment structures of firms differs according to the type of productive technologies in use, and to the types of skills that the firms rely on. Therefore, as in the case of hardware, the use of new HRM practices should provide different levels of benefits to firms in different industries with specific forms of learning, innovation and competition (Malerba, 1992; Coombs and Hull, 1998; Datta *et al*., 2005). Teece (1996) argues that the emergence of novel organizational and managerial practices in a particular sector may be associated with its particular issues.

While some studies investigate the joint adoption of specific productive technologies and organizational practices (Bresnahan *et al*., 2002; Greenan, 2003; Ichniowski and Shaw, 2003), how technological learning environments relate to firms' organizational forms is generally overlooked in the literature. The present study examines the relationship between firms' technological learning environments and their use of innovative HRM practices. In other words, we conduct an empirical investigation of the joint occurrence of technological learning and organizational learning processes.

3. HRM practices and technological learning environments

In this section, we discuss different technological learning environments and develop our expectations about the different use of HRM practices by firms active in these environments.

3.1. Identifying technological learning environments

Using a dataset of some 2,000 innovations developed by British firms between 1945 and 1979, Pavitt (1984) distinguishes four sectors—*supplier-dominated, scale-intensive, specialized-supplier* and *science-intensive*—based on sources of technology, user requirements, direction of technological change, and means of and possibilities for the appropriation of innovation. Based on this, Marsili (2001, 2002) proposed a more refined industry classification that accounts also for market structure, level of entrepreneurship, technological entry barriers and technological opportunities. In this classification, Pavitt's categories are extended into: *science-based, fundamental-product, complex-product, product-*

engineering and *continuous- process*. A further development was made by Miozzo and Soete (2001) who extend the categorization to include services and distinguish three technological environments—*supplier-dominated services (*personal, social and public services)[3], *scale-intensive services* (physical and information network services) and *science-based/ specialized supplier services* (i.e. *technology-intensive services*[4] that serve specialized markets).

All these taxonomies are based on the idea that different industrial activities take place within different technological and learning trajectories and, consequently, that firms develop specific innovative behaviours through the accumulation of different technological and organizational capabilities (Castellacci, 2008). We rely on these industrial taxonomies to define the technological learning environments of firms. Table 1 summarizes the characteristics of the seven technological learning environments considered.

[Insert Table 1 about here]

3.2. HRM practices and technological learning environments

A crucial feature of the taxonomies discussed above is the heterogeneity of technological learning environments, a heterogeneity that extends also to HRM practices. An important source of this heterogeneity in HRM is the way that they foster knowledge creation (i.e. through socialization, externalization, internationalization and combination) (Nonaka, 1994). A second source of heterogeneity is the type of agent involved in the process of knowledge creation (i.e. top-management, teams of employees or individuals) (Nonaka, 1994). These sources of heterogeneity, allow us to categorize HRM practices in the 1990s as decentralizing, problem-solving, or top-down. [5]

Decentralizing HRM practices encourage employees' participation in the identification of learning and technological opportunities, and the development of information-sharing and knowledge externalization (Dean *et al.*, 1992; Mookherjee, 2006; Acemoglu *et al.*, 2007).

Problem-solving HRM practices refer to practices designed to co-ordinate the process of knowledge creation through a combination of skills and resources within a specific mission (Ichniowski and Shaw, 1999, 2003). *Top-down* practices include the use of assessment and performance indicators and the development of channels for the transfer of information and firm-wide objectives (often related to productivity and costs), creating incentives for the internalization of top-management's strategies (Snell, 1992; Fruin and Nakamura, 1997). *Decentralizing*, *problem-solving* and *top-down* HRM practices provide non-financial incentives for learning and for increased individual or group performance. *Rewarding practices* create financial incentives for employees' involvement in the achievement of the firm's objectives, often by connecting remuneration with performance - of the firm, of teams or of individuals (Estrin *et al*., 1987; Ciancanelli *et al*., 1997; Bloom and van Reenen, 2007).

Since organizational and HRM practices are mechanisms that support knowledge accumulation and integration as well as learning and innovation within firms, we would expect the diffusion of the four types of practices to be uneven across technological learning environments. Different technological learning environments require the integration of different and specific scientific and technological advances, and the management and co-ordination of different internal and external sources of knowledge.

In encouraging employees to participate, learn and share information, the use of *Decentralizing practices* reflects the acknowledgement of top-management that employees and shop-floor managers may hold important information than is freely available in the firm, to improve processes (Acemoglu *et al*., 2007; Bloom and Van Reenen, 2007). Thus, decentralizing practices are expected to be important in environments where firms deal with new technologies and little publicly available information, and in environments where industry partners are so different that there is little opportunity to learn from their experience (Acemoglu *et al*., 2007). We would expect decentralizing practices to be exploited particularly in environments characterized by high innovation opportunities and the presence of knowledge spillovers across technologies, products and components, for example, science-based and complex-product environments (Wang and von Tunzelmann, 2000; Marsili, 2002). In the service industries, the significance of decentralizing practices may be that employees, involved in their production and delivery are likely to be the best informed about users' needs and the necessity for design improvements (Miozzo and Soete, 2001).

Top-down practices, which are aimed at monitoring performance and achieving targets in addition to sharing information about the firm's objectives, help to translate firm wide objectives into numerical targets, based on the information available to top management. Such practices may be particularly important in firms that need to improve production efficiency to respond to price competition (Snell, 1992; Fruin and Nakamura, 1997; Acemoglu *et al*., 2007). Thus, we would expect them to be adopted relatively more in environments where technology development and improved competitiveness are associated with intensive production, for example, manufacturing activities, especially in complex and product-engineering environments (Marsili, 2002). In services, we would expect top-down practices in scale-intensive environments since, in these environments, services rely heavily on their production and network engineering skills for innovation and technology development (Miozzo and Soete, 2001).

Rewarding practices are aimed at creating financial incentives for employees to make greater efforts to achieve firm objectives. They may be of most relevance to firms where (market, technological and production) objectives and performance are easily identified and associated with individuals or groups of individuals that are able to work autonomously (Ichniowski and Shaw, 2003). Rewards may be particularly important where the 'base' wage is the marginal labour cost, in which case the introduction of rewarding practices might reduce the firm's average labour costs (Estrin *et al*., 1987: 39). Thus, we would expect rewarding practices to be more widespread in services than in manufacturing. In most service activities, firm profitability is directly affected by employee performance, since the latter are involved directly in the production, sale and delivery of a service. Consequently, a balance between base wage and profit sharing is generally easier to negotiate with employees in the service industries (Estrin *et al*., 1987; Ichniowski and Shaw, 2003), although supplier-dominated services are an exception. This is because of the nature of their services (personal), the specificity of sources of advantage (location), and the small average size of the workplace (Miozzo and Soete, 2001). In manufacturing, rewarding practices may be particularly efficient at encouraging employee participation in the major innovation efforts of firms in science-intensive and fundamental-process technological environments (Ichniowski and Shaw, 2003). In these environments, assessing new market prospects (science-based) and production-cost levels (fundamental-process) is crucial. Thus, rewarding practices may be easier to implement in these industries and be of greater value than in other manufacturing activities.

By creating a space for sharing and using employees' 'sticky' knowledge, *Problem-solving practices* are significant to innovation requiring access, transfer and articulation of multiple sources of embodied knowledge (Von Hippel, 1994). Hence, in technological environments with high innovation and learning opportunities, difference information sources need to be exploited, making problem solving practices crucial (Cohen and Levinthal, 1990). HRM practices to create incentives for problem-solving, for example, team-working, quality-circles, and project-based organizational forms, became widespread during the 1990s based on mimetic or responsive behaviour (Abrahamson and Fairchild, 1999; Pettigrew and Fenton, 2000). In turn, this may have contributed to the emphasis on shorter new product development times (Wang and von Tunzelmann, 2000). Also, to a, extent, all firms employ routines for searching, understanding, and resolving failures and problems (Dosi and Marengo, 2007), which do not necessarily involve team work, although some firms might report this activity as problem-solving (Huczynski, 1993). Hence, we would expect problem-solving practices to be more uniformly used than other HRM practices across technological learning environments. We would also expect them to be slightly more important for activities where competitive advantage is based on factors other than price and location.

The use of combination of HRM practices rather than application of individual practices may enable firms to create organizational forms with higher incentives for learning-by-doing, learning-by-interacting and learning-by-searching and, consequently, allow the achievement of higher performance (Milgrom and Roberts, 1995; Ichniowski and Shaw, 1999; Massini and Pettigrew, 2003). By enabling a coherent learning incentive structure and the development of organizational competences to address major learning challenges, we would expect that combining these four types of innovative HRM practices would be particularly beneficial for firms active in complex activities (Wang and von Tunzelmann, 2000) such as those in science-based and complex-product environments. In science-based environments, the major organizational challenges relate to the management of radical technological change and the application of new ideas and technologies to new products (Pavitt *et al*., 1989). In complex-product environments, the challenge is to integrate several complex types of knowledge and inputs developed internally and externally (Marsili, 2002).

On the other hand, in supplier dominated service industries, where competition is based on location rather than on technological development and expected technology and innovation opportunities are low, the returns from the combined use of innovative HRM practices may be lower (Miozzo and Soete, 2001).

4. Methodology and data

4.1. Data

To understand the differences in the use of HRM practices across technological learning environments, we focus on the 1990s, which was a period when many firms revised their organizational forms to respond to similar learning challenges created by changes in the economic, technological and competitive structure (Whittington *et al*., 1999; Pettigrew and Fenton, 2000). Our empirical analysis employs data from the WIRS dataset of British workplaces for the years 1990 and 1998,[6] which provides detailed and valuable information on HRM practices in British workplaces, and data that are comparable for the beginning and late 1990s. The dataset includes information on nine HRM practices (regular meetings between management and staff; suggestion schemes; quality circles; briefing groups; collection of information on productivity; communication through the management chain; shared investment plans with employees; profit-related pay schemes; share ownership), and the organizational and industrial characteristics of the workplaces. We have 2,061 observations for 1990, and 1,929 observations for 1998. As some of the variables are affected by missing values, our pooled data regressions are based on 1,870 observations of private workplaces. This loss of observations does not seem to bias the analysis.[7] We use non-weighted data, because the sample weights do not account for several workplace characteristics that may influence the level of use of HRM practices (Moore *et al*., 2000; Gelman, 2007).

4.2. Constructing and empirically validating the four types of HRM practices

Section 3 discussed why management practices are not identical in terms of their impact on specific learning processes. We examine four types of HRM practices: decentralizing, top-down, problem-solving and rewarding. To construct these four bundles empirically, we run a hierarchical cluster analysis of the nine HRM practices in the original dataset. Figure 1 is a depiction of the resulting dendrogram. We should stress hierarchical cluster analysis is used to cluster the variables—the nine HRM practices—*not* to group cases (i.e. workplaces). This technique identifies clusters of practices, which, according to their pattern of adoption and impact, can be considered similar.

[Insert Figure 1 about here]

The dendrogram in Figure 1 shows that the nine practices surveyed in WIRS can be grouped within four practice clusters (we want to avoid clusters with only one practice):

- *Decentralizing (bottom-up) informational management practices:* including regular meetings between management and staff, and employee suggestion schemes;

- *Problem-solving practices:* including quality circles and briefing groups;
- *Top-down management practices:* including collection of information on productivity, communication along the management chain, and share investment plans with employees;
- *Rewarding practices:* including profit-related pay schemes and share ownership;

These four groups correspond empirically to the HRM practices introduced in Section 3.2.

To provide a preliminary understanding of these clusters, we examine the correlation between each HRM practice (individually and in the cluster) and the technological learning environment (see Table 2).

[Insert Table 2 about here]

Evidence suggests that coefficients are significant though generally low, especially for manufacturing. However, it is interesting to note that in some cases the coefficients for each cluster tend to be higher than the average coefficients of each individual practice. We can therefore focus on the four identified groups of HRM practices rather than on the individual practices. In so doing, we also account for potential complementarity among the individual practices within each group (Milgrom and Roberts, 1995; Massini and Pettigrew, 2003). Moreover, the degree of inter-relationship between HRM practices and technological learning environments appears not to be uniform. This difference is explored further in Section 5, using empirical regression models that allow us to control for other factors relevant to the firm's decision to implement HRM practices.

The empirical analysis exploits our four clusters of HRM practices (i.e. rewarding, problem-solving, top-down and decentralizing) both separately and in combination, which seems to constitute a reasonable empirical measure of the different types of HRM practice discussed in Section 3.2.

4.3. Econometric modelling

To explore the level of use of HRM practices across technological learning environments we perform regression analysis. We run regressions for the count variable *All*, which indicates how many of the nine individual practices workplaces are exploiting, and for each of the four types of HRM—rewarding, problem-solving, top-down and decentralizing—separately (See Table 3). Our dependent variables are the count of HRM practices (All, Problem-solving, Top-down, Decentralizing and Rewarding) applied in British workplaces. As the dependent variables are non-negative count variables, this might violate homoschedasticity and uncorrelated error terms assumptions in the ordinary least squares regressions. This means that a Poisson regression model is more appropriate (Long and Freese, 2003). To allow for heteroschedasticity and correlation of the error terms within clusters (i.e. technological learning environments), we apply cluster-robust standard errors to our estimates (Cameron and Trivedi, 2005).[8]

To account for the specificity of the technological learning environments discussed in Section 3, we create seven dichotomous variables based on the two-digit industry classification for firm activity (see Table 3).[9]

To highlight the importance of technological learning environments for explaining level of use of HRM practices, the models include additional controls for the organizational and market characteristics of workplaces, and for the most frequently used channels of diffusion of management practice, which has been acknowledged to influence organizational learning and the use of specific management practices. We also take account of the environmental conditions of adoption since the factors influencing innovation adoption may evolve over time (Battisti and Stoneman, 2005).

Following the discussion in Section 2, to characterize firms' organizational and market specificities, we include variables for firm size (*size* and *sqsize*), foreign ownership (*foreign*), being part of a group (*group*), the most significant market for the firm (*local and international*), and whether the firm produces one or many products (*mproduct*). To control for other channels of diffusion of information within the firm, we use two dichotomous variables: *advice*, which captures information about the use of consultancy advice on HRM, and *association*, which provides information on whether or not the establishment is a member of the EA (Employers' Association). Since it is not possible to construct panel data that includes variables relevant to this analysis based on observations for 1990 and 1998, we pool the data and control for time trends. We do this by including, for all the variables described, the interaction with the variable '*year*', which takes the value 0 for observations in 1990 and 1 for observations in 1998. We run this model for manufacturing and services separately and pooled. Table 3 presents the dependent and explanatory variables. The descriptive statistics and correlation coefficients for all the dependent and independent variables respectively, are presented in Tables 4 and 5.

[Insert Table 3 and 4 and 5 about here]

5. Technological learning environments and organizational learning incentives

5.1. Empirical analysis

Poisson estimates of the level of use of *All* HRM practices for the pooled data and for manufacturing and services separately, are presented in Table 6; estimates of the level of use of each type of HRM practice for the pooled data, and for manufacturing and services separately are reported in Tables 7 and 8. Table A1 in the appendix provides information on the significance of the differences among the sector coefficients in the regressions for the pooled data, and for manufacturing and services separately.

[Insert Table 6 about here]

Results for the pooled data (Table 6, column 1, see also Table A1) suggest that the level of use of all nine HRM practices differs across technological learning environments. Workplaces involved in complex-product and science-based manufacturing activities, followed by fundamental process and scale-intensive services, tend to show the highest levels of use of HRM practices while supplier-dominated services register the lowest levels of use.

Columns 2 and 3 in Table 6 report the results for manufacturing and services considered separately. The results highlight important differences in the factors correlated with use of HRM practices in services and manufacturing. While the results for services generally mirror those obtained in the pooled regressions, in the case of manufacturing, there are some important differences. In particular, in services the use of HRM practices is more intensive in workplaces with multiple-product portfolios and workplaces that relied on consultancy advice especially in 1990. In manufacturing, consultant advice is not significant in either period, and the small positive association with a multiple-product portfolio, observed in 1990 is reversed in 1998. Moreover, foreign ownership does not seem to be associated with level of use of HRM practices by manufacturing firms, but is correlated negatively with level of use by service firms. Finally, being member of an EA is associated with the level of adoption of innovative HRM only in the case of services; in 1990 this correlation is negative and in 1998 it is reversed with the coefficient for 1998 positive and significant. A focus on local markets is negatively associated with the level of adoption of innovative HRM practices in manufacturing. In both service and manufacturing activities, we find an inverted U-shaped relationship between workplace size and use of novel HRM practices. Moreover, being part of a group seems to encourage use of a high level of innovative HRM practices. For differences across technological learning environments, the results are similar to those for the pooled regressions.

Using the same Poisson models, we also estimate the level of use of the four types of HRM practices —problem-solving, top-down, decentralizing and rewarding.

[Insert Table 7 about here]

The results for the pooled data (Table 7) suggest that different factors are associated significantly with the level of use of the four specific types of HRM practices—Problem-solving, Top-down, Decentralizing, Rewarding. Again, we find important differences across technological learning environments (see also Table A1). Complex-products manufacturers exhibit the highest level of use of top-down practices, and are significantly different from all other workplace environments. Services, especially supplier-dominated and technology-intensive, are among the least frequent adopters of top-down practices. The use of problem-solving practices is significantly higher for science-based manufacturers, and lower for product-engineering and continuous process manufacturing. The use of decentralizing practices is highest in complex-products and science-based manufacturers, followed by scale-intensive services. Their use is lowest in continuous-process manufacturing. Rewarding practices are more frequent in technology-intensive and scale-intensive services, and less exploited in supplier-dominated services and product-engineering. Finally, supplier-dominated services tend to use all types of HRM practices except problem-solving, where exploitation is lower than all the other sectors considered.

If we break down workplaces into manufacturing and services, we again find important differences (see Table 8). The results for the coefficients of technological learning environments are quite similar to those from the pooled regressions, with minor differences in the use of problem-solving practices in manufacturing (see also Table A1). Use of problem-solving is more uniform, with differences between continuous-process and fundamental-process and continuous process and complex-products, non-significant. For the control variables, we again find important differences compared to the results for the pooled regressions.

[Insert Table 8 about here]

In manufacturing, membership of an EA is not correlated significantly with the use of any type of HRM practice. In the service industries, EA membership seems to reduce the use of problem-solving and decentralizing HRM practices in 1990, but not in 1998. Among services, consultant advice is positive for the adoption of top-down and decentralizing practices, especially in 1990. In manufacturing, consultant advice is significantly and positively correlated only with the use of problem-solving practices.

In services being part of a group tends to promote the use of all types of HRM practices. During the 1990s, being part of a group became relatively less important to the level of use of innovative HRM in the service industries with the exception of rewarding practices, which assume even more importance for these firms in 1998. In manufacturing, being part of a group seems to promote the use of rewarding practice, and especially in 1990.
We find differences between services and manufacturing in relation to the importance of location of the most important market and use of new HRM practices. A focus on local markets by manufacturers is negatively correlated to use top-down practices. In 1998, manufacturing workplaces, operating mainly in local markets, relied relatively less on decentralizing practices and relatively more on problem-solving practices. The use of top-down practices by manufacturers seems higher among workplaces with a national rather than an international market focus, especially in 1998. Among services, a focus on international markets reduces the use of decentralizing practices; decentralizing HRM practices seem mainly exploited by service firms serving national markets in 1990 and by service firms focused on local markets in 1998.

The coefficient of variable for multiple-product portfolio is positive and significant for all types of HRM practices except top-down practices in the case of services. However, in 1998, for manufacturing, this positive correlation is reverted.

Foreign ownership tends to promote the use of certain innovative HRM practices among manufacturers (especially problem-solving and decentralizing informational practices, but not rewarding practices), but not for services (especially top-down and problem-solving practices). Use of rewarding practices in both manufacturing and services is significant lower in workplaces with foreign than with British ownership.

Finally, the inverted U-shaped relationship between workplace size and exploitation of new HRM practices is particularly significant for manufacturing activities. In services it is significant only for rewarding practices, the type in which this relationship is weaker for manufacturing.

5.2. Robustness check

We conducted additional analyses to check the robustness of our results.[10] First, we ran separate Poisson models for the 1990 and 1998 observations, and applied an adjusted Wald Chi-square test to examine the similarity among the coefficients in 1990 and 1998. The coefficients in the separate regressions for 1990 and 1998 are similar in terms of significance and the sign of the coefficients to those for the pooled regressions presented in Section 5.1.

This exercise provides additional information on the level of use of HRM practices across technological learning environments. The results suggest that, during the 1990s, science-based and fundamental-process manufacturers, on average, increased their use of HRM practices, while product-engineering and complex-product made less use of them. Hence, in 1998 complex-product manufacturers are not the heaviest users of all innovative HRM practices; they exploit them to a similar extent to continuous-process manufacturers. Also, during the 1990s, the gap with supplier-dominated services decreased, especially for top-down and decentralizing practices, while the use of rewarding practices declined. However, the pattern of use of different types of HRM practice is similar to that reported in Section 5.1.

The literature suggests that the use of innovative HRM practices may be associated with higher levels of performance and competitiveness (Ichniowski and Shaw, 1999; Bloom and van Reenen, 2007). During the 1990s, the relative economic importance of the different technological learning environments in the UK changed (OECD, 2005). Whether or not these results reflect the general loss of competitive advantage among British complex-product and product-engineering manufacturing activities in the 1990s and the increased importance of science-based and service industries is a topic for future research.

As a further robustness check, we ran a multivariate probit analysis, which allows simultaneous estimation of more than one binary probit equation with correlated disturbances (Galia and Legros, 2004). This requires the use of dichotomous variables; we therefore estimated the probability that a workplace uses 100% of each type of HRM practices. In other words, although lower levels of use of some HRM practices may create economic benefits for some workplaces, we assume that 100% is the optimal level of use of each type of practice. The results of the multivariate probit are very similar to the results in Section 5.1. The differences in the coefficients of technological learning environments are as follows. In the pooled manufacturing and services model, the use of problem-solving practices by fundamental-process manufacturers, scale-intensive services and supplier-dominated services do not differ significantly from that of continuous-process manufacturers. In the service model, supplier-dominated and technology-intensive services use top-down practices to the same extent. Hence, correlations among use of the four types of practice do not seem to have biased the Poisson estimates significantly.

5.3. Discussion

Our analysis suggests that the largest users of new HRM practices are firms active in complex-products, science-based activities, scale-intensive services, and fundamental-process activities. Supplier-dominated services show the smallest level of use of HRM practices. As expected, in technological learning environments where technological opportunities are high and factors, other than location and price (such as technology, knowledge integration and customer relations) are important in determining firm competitiveness, firms tend to rely relatively more on HRM practices. Firms in these environments tend to use practices that support the creation of a working environment that is more favourable to improvement and innovation, by facilitating bottom-up information flows and employee participation and learning.

Although similar learning challenges and access to managerial information channels and some workplace-specific characteristics seem to have much the same effect on the use of some practices across sectors, HRM practices seem not to be suited equally to all technological learning contexts. Our results suggest that different HRM practices create specific learning incentives relevant to workplaces active in specific technological learning environments.

In particular, traditional top-down practices, aimed at encouraging and controlling the achievement of firm-wide objectives related to productivity and costs, are more beneficial in productive and competitive manufacturing environments, especially those not producing for local markets. This finding points to the importance of cost control and process efficiency for enhancing the competitiveness of most manufacturers. Rewarding practices seem better suited to firms active in services whose performance and competitiveness is often directly associated to specific employee behaviour and direct customer satisfaction. Decentralizing HRM practices that favour bottom-up informational flows and employee participation are more appropriate for manufacturing and services industries where developing an innovative environment that favours learning-by-doing, knowledge integration and customer feedback is crucial.

The use of problem-solving practices aimed at encouraging knowledge sharing and creation, seem to be influenced more by access to managerial information, through different channels at different times (i.e. affiliated firms, peers members of EA, consultant advice, reputation in local markets), than by the technological learning environment. This result is consistent with the findings from other studies, which show that the diffusion of some problem-solving practices the result of mimicking or responsive behaviour (Abrahamson and Fairchild, 1997; Massini *et al*., 2002; Nelson *et al*., 2004). In this study, we were unable to differentiate mimetic from responsive behaviour in relation to the use of HRM practices resulting from the dissemination of information.

Alongside the role of technological learning environments, our results highlight also that the use of specific types of HRM practices is influenced by firm characteristics. Generally our results are consistent with evidence about the influence of size, being part of a group and foreign ownership, on the use of innovative HRM practices (Kotey and Slade, 2005; Massini *et al*., 2005; Brysson *et al*., 2007). The evidence suggests that the market characteristics of a firm based on its product portfolio and location of its most important market, affect the adoption of HRM practices.

The evidence in this paper suggests also that some organizational, relational and market characteristics of workplaces have an uneven effect on the adoption of HRM practices in manufacturing and services, and that this influence also is not constant over time. In particular, the influence of different information channels seems not to be similar for services and manufacturing, which suggests that management trends (based on mimicking and/or responsive behaviour) rely on different compelling and informative mechanisms and channels that are industry and time specific. If this is the case, then sector specific challenges/trends may create as many differences in the use of HRM practices as the technological learning environments in which firms operate. Unfortunately, we are unable to disentangle the effect of these factors at sector level.

Overall, our results suggest that the level of use of HRM practices by firms is associated with the technological learning environment in which they are active rather than only with their organizational and market characteristics, and their level of exposure to information on management best-practice.

6. Overview and conclusions

The aim of this paper was to analyse the co-occurrence of technological and organizational learning processes by looking at the adoption and use of HRM practices. We examined a sample of British workplaces from the WIRS dataset and analysed the importance of the use of different types of HRM practices in the 1990s, across technological learning environments. Our evidence shows that there are differences in the intensity of use of HRM practices across technological learning environments, defined according to the taxonomies proposed by Pavitt, Marsili and Miozzo and Soete. These taxonomies seem to capture very well the main cross-firm differences in the intensity of use of rewarding, problem-solving, top-down and decentralizing informational management practices. The use of problem-solving practices seems to be associated mainly with access to managerial information through different channels, and with certain firm characteristics.

Our evidence shows also that the organizational, market and relational characteristics of firms are associated with the level of use of different types of HRM practices, which provide distinct learning incentives. However, this association varies across technological learning environments and differs between manufacturing and services firms. In light of these results, we can conclude that HRM may form an essential part of the learning structure of firms, and use of HRM practices is heterogeneous across firms active in different technological learning environments. Hence, rather than an horizontally driven process by imitation and/or by similar responses to the changing competitive environment, the use of most HRM practices also reflects a firm's organizational and industrial specificities in terms of technology, sources of innovation and learning, and coordination.

Although these results are interesting, this analysis has some limitations. First, it is a single country analysis. The national learning environment may shape the capabilities of firms, and affect firms' evaluation of the benefits of using HRM practices. Moreover, industries tend to have different characteristics across countries. There are strong national differences in the use of different organizational practices and in the complementarites in the use of HRM practices (Massini and Pettigrew, 2003). Nevertheless, the adoption of comprehensive systems of novel HRM practices may provide similar levels of performance among firms in different countries (Ichniowski and Shaw, 1999).

Second, this study relies on cross sectional rather than panel data. Despite controlling for several organizational, market and relational characteristics of firms, we are unable to illustrate the effect of specific cultural organizations on the use of HRM practices. Third, this study focuses on HRM practices related to the internal organization of firms and ignores practices, such as social relational practices with external partners, which are important for firms' innovation activities (Subramaniam and Youndt, 2005).

More research is needed to explore cross-country differences and the role of firms' organizational culture specificities on the heterogeneous use of different organizational and managerial practices across technological learning environments. Also, although some authors show that different levels of innovation adoption are associated with different benefits (Battisti and Stoneman, 2005), more work is required to examine whether or not the level of performance from the use of similar HRM practices across technological learning, is uniform.

[1] It would be tempting to use the term ‘complementarity’ between technological learning environments and organizational practices rather than ‘co-occurrence’. Indeed the existing literature suggests that two types of complementarity may exist: complementarity in performance and complementarity in adoption. While the former refers to the impact of organizational practices on firm output (Athey and Stern, 1998), the latter refers to the joint use of a set of practices (Cassiman and Veugelers, 2006). Since we lack performance measures, in our case complementarity would be understood as complementarity in adoption. However, given that also organizational practices are likely to be adopted in cluster (when they are ‘complements’), talking about complementarity between practices and learning is most likely to cause misunderstandings. Thus, throughout the paper we will use the term ‘co-occurrence’ to indicate the fact that some organizational practices are more likely to be used in specific technological environments rather than others as a consequence of the specific type of learning that characterises the environments. We thank an anonymous reviewer for urging us to specify this point.

[2] In 1998, the name of this dataset became the Workplace Employee Relations Survey.

[3] In particular, since the end of 1980s, the traditional boundaries between public and private service sectors have been weakened as governments have turned to the private sector for the provision of several public services, and as new public management has been introduced in public administrations in terms of the use of private management tools and HRM practices (Miozzo and Soete, 2002, p. 162). The sources of technology and innovative trajectories are similar in private and in public services.

[4]These services experienced major growth during the 1990s due to developments in ICT, which allowed services to be produced and consumed in different places at reduced costs, and to the increased outsourcing of activities traditionally internalized by large firms, such as accounting, advertising and distribution, among others (Miozzo and Soete, 2002).

[5] This categorization of HRM practices into decentralizing, problem-solving, top-down and rewarding also covers the firm’s different management areas as proposed in Bloom and Van Reenen (2007): Operations, Targets, Monitoring, and Incentives.

[6] The WIRS dataset is based on a British firm survey carried out in 1980, 1984, 1990, 1998, and 2004 on working environments and employment relations.

[7] Compared to the full sample, for which there are some missing values, our sample (1,870 workplaces) comprises on average more independent workplaces, of smaller size, which are less likely to be active in supplier-dominated services activities. To an extent, under-sampling of supplier-dominated services provides a more balanced sample of workplaces across sectors. This selection might also introduce less significant differences between supplier-dominated services and other sectors because the supplier-dominated workplaces included in our sample focus relative less on international markets and include a slightly lower level of adoption of *All* HRM practices.

[8] Results with non-clustered robust standard errors provide similar results to those included in this paper. They are available from the author.

[9] Lack of information on 3-digit industry classifications prevents us from separating real estate from business services activities and financial and leasing from banking and insurance activities. Thus, variety in the technology-intensive service sector might be higher in our analysis than in reality.

[10] For space reasons, results are not reported in the text. They are available upon request from the authors.

References

Abrahamson, E. (1991), 'Managerial fads and fashions: The Diffusion and rejection of innovations', *Academy of Management Review*, **16**, 586-612.

Abrahamson, E. and G. Fairchild (1999), 'Management fashion: lifecycles, triggers and collective learning processes', *Administrative Science Quarterly*, **44**, 708-740.

Abrahamson, E. and L. Rosenkopf (1993), 'Institutional and competitive bandwagons: using mathematical modelling as a tool to explore innovation diffusion', *Academy of Management Review*, **18**, 487-517.

Acemoglu, D., P. Aghion, C. Lelarge, J. van Reenen and F. Zilibotti (2007), 'Technology, information, and the decentralization of the firm', *Quarterly Journal of Economics*, **122** (4), 1759-1799.

Alvesson, M. and D Kärreman. (2007), 'Unraveling HRM: Identity, Ceremony, and Control in a Management Consulting Firm', *Organization Science*, **18**, 711–723.

Athey, S. and Stern, S. (1998). 'An Empirical Framework for Testing Theories About Complementarities in Organizational Design'. *NBER Working Paper* #6600.

Barney, J. B. and P. M. Wright (1998),'On becoming a strategic partner: the role of human resources in gaining competitive advantage'. *Human Resource Management*, **37** (1), 31-46

Battisti, G. and P. Stoneman (2005), 'The intra-firm diffusion of new process technologies', *International Journal of Industrial Organization*, **23**, 1-22.

Bloom, N. and J. van Reenen (2007), 'Measuring and explaining management practices across firms and countries', *Quarterly Journal of Economics*, **122** (4), 1351-1408.

Bresnahan, T.F., E. Brynjolfsson and L. M. Hitt (2002), 'Information technology, workplace organization, and the demand for skilled labor: firm-level evidence', *Quarterly Journal of Economics*, **117**, 339-376.

Bryson, A., R. Gomez,, T. Kretschmer and P. Willman (2007), 'The diffusion of workplace voice and high-commitment human resource management practices in Britain, 1984-1998', *Industrial and Corporate Change*, **16**, 395-426.

Cabrales, A.L., C. C Medina, A. C. Lavado and R. V. Cabrera (2008), ‘Managing functional diversity, risk taking and incentives for teams to achieve radical innovations’, *R&D Management*, 38, 35-50.

Cameron, A. C., and P. K. Trivedi (2005), *Microeconometrics: Methods and Applications*, Cambridge University Press.

Caroli, E. and J. van Reenen (2001), ‘Skill-based organizational change? Evidence from a panel of British and French establishments’, *Quarterly Journal of Economics*, **116**, 1449-1492.

Cassiman, B. and R. Veugelers (2006), ‘In Search of Complementarity in the Innovation Strategy: Internal R&D and External Knowledge Acquisition’, *Management Science*, 52, 68-82.

Castellacci, F. (2008), ‘Technological paradigms, regimes and trajectories: Manufacturing and services industries in a new taxonomy of sectoral patterns of innovation’. *Research Policy* **37**, 978-994

Ciancanelli, P., S., Gallhofer, J. Haslam and R. Watson (1997), ‘Profit Related Pay and the U.K. Small Firm Labour Market’, *Small Business Economics*, **9**, 225–238.

Cohen W. M. and D. A. Levinthal (1990), ‘Absorptive Capacity: A New Perspective on Learning and Innovation’, *Administrative Science Quarterly*, **35**, 128-152

Coombs, R. and R. Hull (1998), ‘Knowledge management practices’ and path-dependency in innovation’, *Research Policy*, **27**, 237–253.

Coriat, B. and G. Dosi (2002), ‘The Nature and Accumulation of Organizational Competences/Capabilities’, *Revista Brasileira de Inovação*, **1**, 275- 326

Coriat, B. and O. Weinstein (2002), ‘Organizations, firms and institutions in the generation of innovation’, *Research Policy*, **31**, 273-290.

Datta, D., J. Guthrie and P. Wright (2005), ‘HRM and labor productivity: does industry matter?’, *Academy of Management Journal*, **48**, 135– 145.

Dean, J.W., S. J. Yoon and G. I. Susman (1992) ‘Advanced Manufacturing Technology and Organization Structure: Empowerment or Subordination?’ *Organization Science*, **3**, 203-229

Dosi, G. (1997), ‘Opportunities, Incentives and the Collective Patterns of Technological Change’, *The Economic Journal*, **107**, 1530-1547.

Dosi, G. and L. Marengo (2007), ‘On the Evolutionary and Behavioral Theories of Organizations: A Tentative Roadmap’, *Organization Science*, **18** (3), 491–502.

Dosi, G., D. Levinthal and L. Marengo (2003), ‘Bridging contested terrain: Linking incentive-based and learning perspectives on organizational evolution’, *Industrial and Corporate Change,* **12**, 413-436.

Estrin, S., P. Grout, S. Wadhwani, S. J. Nickell and M King. (1987), ‘Profit-Sharing and Employee Share Ownership’. *Economic Policy*, **2**, 13-62.

Fruin, W.M. and M. Nakamura (1997), ‘Top-down Production Management: A recent trend in the Japanese productivity-enhancement movement’, *Managerial and Decision Economics*, **18**, 131-139.

Galia, F. and D. Legros (2004), ‘Complementarities between obstacles to innovation: evidence from France’, *Research Policy,* **33**, 1185-1199.

Gelman, A. (2007), ‘Struggles with Survey Weighting and Regression Modeling’, *Statistical Science*, **22**, 153–164.

Godard, J. and J. T. Delaney (2000), ‘Reflections on the "High Performance" Paradigm's Implications for Industrial Relations as a Field’, *Industrial and Labor Relations Review*, **53**, 482-502.

Granstrand, O., P. Patel and K. Pavitt (1997), ‘Multi-Technology Corporations: why they have "distributed" rather than "distinctive core" competencies’, *California Management Review*, **39**, 8-25.

Greenan, N. (2003), ‘Organisational change, technology, employment and skills: and empirical study of French manufacturing’, *Cambridge Journal of Economics*, **27**, 287-316.

Haunschild, R. and A. S. Miner (1997), ‘Modes of interorganizational imitation: the effects of outcome salience and uncertainty’, *Administrative Science Quarterly*, **42**, 472-499.

Hendry C. and A. Pettigrew (1992), ‘Patterns of Strategic Change in the Development of Human Resource Management’ , *British Journal of Management,* **3**, 137-156.

von Hippel, E. (1994), ‘Sticky Information" and the Locus of Problem Solving: Implications for Innovation’, *Management Science*, **40** (4), 429-439

Huczynski, A. A. (1993), *Management Gurus, What Makes Them and How to Become One*. Routledge: London and New York.

Huselid, M. A. (1995), ‘The Impact of Human Resource Management Practices on Turnover, Productivity, and Corporate Financial Performance’, *The Academy of Management Journal,* **38,** 635-672.

Ichniowski, C., K. Shaw and G. Prennushi (1997), ‘The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines’, *The American Economic Review,* **87**, 291-313.

Ichniowski, C. and K. Shaw (2003), ‘Beyond Incentive Pay: Insiders’ Estimates of the Value of Complementary Human Resource Management Practices’, *Journal of Economic Perspectives,* **17** (1), 155-178

Ichniowski, C. and K. Shaw (1999), ‘The effects of Human Resource Management Systems on Economic Performance: An International Comparison of U.S. and Japanese Plants, *Management Science*, **45** (5), 704-721

Kor, Y.Y. and J.T. Mahoney, (2004), ‘Edith Penrose’s (1959) Contributions to the Resource-based View of Strategic Management’, *Journal of Management Studies,* **41**(1), 183-191

Kotey, B. and P. Slade (2005), ‘Formal Human Resource Management Practices in Small Growing Firms’, *Journal of Small Business Management,* **43**, 16–40

Lai, H-C. Y-C. Chiu, Y-C. Liaw and T-YLee (2010), ‘Technological Diversification and Organizational Divisionalization: the Moderating Role of Complementary Assets’, British Journal of Management, forthcoming.

Lepak, D. P., M. S. Taylor, A. Tekleab, J. A. Marrone and D. J. Cohen (2007), ‘An examination of the use of High-investment Human Resource Systems for core and support employees’, *Human Resource Management*, **46**, 223–246.

Long, J. S., and J. Freese (2003), *Regression models for categorical dependent variables using Stata*. Stata Press: College Station, Texas.

Macky, K. and P. Boxall (2007), ‘The relationship between 'high-performance work practices' and employee attitudes: an investigation of additive and interaction effects’, *The International Journal of Human Resource Management*, **18**, 537–567.

Malerba, F. (1992), ‘Learning by firms and incremental technical change’, *The Economic Journal*, **102**, 845-859.

Malerba, F. and L. Orsenigo (1997), ‘Technological Regimes and Sectoral Patterns of Innovative Activities’, *Industrial and Corporate Change*, 6, 83-117.

Marsili, O. (2001), *The Anatomy and Evolution of Industries: Technological Change and Industrial Dynamics*. Edward Elgar: Cheltenham, UK and Northampton, MA.

Marsili, O. (2002), ‘Technological Regimes and Sources of Entrepreneurship’, *Small Business Economics*, **19**, 217–231.

Massini, S., A. Y. Lewin and H. R. Greve (2005), ‘Innovators and imitators: Organizational reference groups and adoption of organizational routines’, *Research Policy*, **34**, 1550-1569.

Massini, S., A. Y. Lewin, T. Numagami and A. M. Pettigrew (2002), ‘The evolution of organizational routines among large Western and Japanese firms’, *Research Policy*, **31**, 1333-1348.

Massini, S. and A.M. Pettigrew (2003), ‘Complementarities in Organizational Innovation and Performance: Evidence from the INNFORM Survey. 133-171. in A.M. Pettigrew, R. Whittington, L. Melin, C. Sanchez-Runde, F. van den Bosch, W. Ruigrok and T. Numagami (eds.) *Innovative Forms of Organizing. International Perspectives*. SAGE, London.

Michie, J. and M. Sheehan (1999), ‘HRM Practices, R&D Expenditure and Innovation Investment: Evidence from the UK's 1990 workplace Industrial relations survey (WIRS)’, *Industrial and Corporate Change,* **8**, 211-234.

Milgrom, P. and J. Roberts (1995), ‘Complementarities and fit strategy, structure, and organizational change in manufacturing, *Journal of Accounting and Economics*, **19,** 179 - 208.

Miozzo, M. and L. Soete (2001), ‘Internationalization of Services: A Technological Perspective’, *Technological Forecasting and Social Change*, **67**, 159-185.

Mookherjee, D. (2006), ‘Decentralization, Hierarchies, and Incentives: A Mechanism Design Perspective’, *Journal of Economic Literature*, **44**, 367-390.

Moore, W., S. Pedlow, P. Krishnamurty and K. Wolter (2000), National Longitudinal Survey of Youth 1997 (NLSY97) Technical Sampling Report. NORC: Chicago.

Nelson, R. R., A. Peterhansl and B. Sampat (2004), ‘Why and how innovations get adopted: a tale of four models’, *Industrial and Corporate Change,* **13**, 679-699.

Nonaka, I. (1994). ‘A dynamic theory of organizational knowledge creation’, *Organization Science*, **5**(1), 14-47.

OECD, (2005). The OECD STAN Industry database. OECD (Organisation for Economic Co-operation and Development).

Pavitt, K. (1984), ‘Sectoral patterns of technical change: towards a taxonomy and a theory’, *Research Policy*, **13**, 343-373.

Pavitt, K., M. Robson and J. Townsend (1989), ‘Technological accumulation, diversification and organisation in UK companies, 1945-83’, *Management Science*, **35**, 81-99

Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. New York: John Wiley.

Pettigrew, A. M., and E. M. Fenton (2000), *The Innovating Organization.* Sage: Thousand Oaks, CA.

Ramsay, H., D. Scholarios and B. Harley (2000), ‘Employees and High-Performance Work Systems: Testing Inside the Black Box’, *British Journal of Industrial Relations*, **38**, 501-531.

Snell, S. A. (1992), ‘Control theory in strategic human resource management: the mediating effect of administrative information’, *Academy of Management Journal*, **35**(2), 292-327.

Subramaniam, M., and M. A. Youndt (2005). The influence of intellectual capital on the types of innovative capabilities. *Academy of Management Journal*, **48**(3) 450–463.

Teece, D. J. (1996), ‘Firm organization, industrial structure and technological innovation’, *Journal of Economic Behavior and Organization*, **31**, 193-224.

Wang, Q. and N. von Tunzelmann (2000), ‘Complexity and the function of the firm: breadth and depth’, *Research Policy*, 29, 805-818.

Whittington, R., A. Pettigrew, S. Peck, E. Fenton and M. Conyon (1999), ‘Change and Complementarities in the New Competitive Landscape: A European Panel Study, 1992-1996’, *Organization Science*, **10**, 583-600.

Table 1. The characteristics of the technological learning environments

Sector	Industries	Sources of knowledge/ technology	Type of user	Nature of innovation/ persistence and opportunity	Technology trajectory	Entry barriers / Sources of entrepreneurship	Means of appropriation	Relative size of innovating firms	Inter-firm diversity*
Science-based	Pharmaceutical; electrical and optical equipment	Public institutions and joint ventures Strong and direct link with academic research In-house R&D, product engineering	Price and Performance sensitive	Product & Process High innov. persistence High technological opportunity (applications engineering)	Cost-cutting Product design	High knowledge entry barriers (cumulativeness of knowledge)	R&D, know-how; patents; process secrecy, dynamic learning capabilities	Large	Low
Fundamental-process	Chemicals, except pharmaceuticals	Production engineering Affiliated firms and users Quite important direct links with academic research	Price sensitive	Process High innov. persistence Medium technological opportunity	Cost-cutting (product engineering)	High scale entry barriers (cumulativeness of knowledge)	Process secrecy and know-how; technical lags, patents	Large	Medium (low differentiation of knowledge basis)
Product-engineering	Mechanical machinery and equipment	In-house design and engineering Large Users Quite important indirect links with academic research (engineering)	Performance sensitive	Product Medium-low innov. Persistence Medium-high technological opportunity	Product design: reliability, performance	Low barriers (pervasiveness of knowledge; diversity of technology trajectories; users as sources of knowledge)	Design, know-how, knowledge of users; patents	Small	High
Complex-product	Transport equipment	In-house and complex system of sources of knowledge and inputs (suppliers, users, institutions,)	Price and Performance sensitive	Product High innov. Persistence Medium technological opportunity	Cost-cutting (product design)	Medium-high entry barriers, (complexity of the internal and external knowledge bases)	Process secrecy and know-how; technical lags, patents and dynamic learning	Large	High

		Quite important indirect links with academic research (engineering)					capabilities		
Continuous-process	Food; textiles; leather; wood; pulp and paper; publishing and printing; fabricated metals; other non-metallic mineral; other manuf.	Suppliers of capital embodied knowledge, Links with academic research are not very important, except for metallurgy, materials and food	Price sensitive	Process Low innov. persistence (high in metals and materials) Low technological opportunity	Cost-cutting	Low barriers (diversity of innovation strategies; embodied knowledge)	Non-technical (trademarks; marketing; advertising; aesthetic design)	Small (mixed)	High
Supplier-dominated services	Construction; hotels and restaurants; education; health; other social and personal services; public administration.	Suppliers of capital-embodied knowledge (equip; inform; materials)	Performance sensitive	Product/service Low innov. Persistence Low technology opportunity	Service/ Product design	Low entry barriers (professional skills; embodied knowledge)	Non-technical (location, advertising, trademarks; professional skills,	Small (large in public and social services)	High
Scale-intensive services	Wholesale; transport, storage and distribution; electricity, gas and water supply, financial interm.	Manufacturing and services suppliers In-house networking engineering	Price sensitive	Process Medium innov. Persistence Medium technology opportunity	Cost-cutting Networking	Low entry barriers (scale)	In-house network engineering and know-how; standards, norms; advertising	Large	Medium
Technology-intensive services	Business-to-business services and R&D activities;	In-house engineering/ skills, customers and suppliers	Performance sensitive	Product/service Medium-high innov. persistence Medium-high technology opportunity	Service systems design	Medium entry barriers (knowledge and users)	R&D, know-how, skills; copyrights; product differentiation	Small	High

Sources: Pavitt (1984), Pavitt *et al.* (1989), Marsili (2001, 2002), and Miozzo and Soete (2001)
* in terms of size and knowledge bases

Table 2. Correlation coefficients between technological learning environments and individual and bundles of HRM practices.

	Fundamental proc.	Science-base	Complex prod	Product eng.	Continuous	Serv scale	Serv dominated	Serv technology
Rewarding	**0.02**	**0.01**	**0.004**	**-0.04**	**-0.08****	**0.19****	**-0.22****	**0.09****
profit-related pay scheme	0.03	0.01	-0.03	-0.04	-0.09**	0.12**	-0.14**	0.11**
share ownership scheme	0.003	0.003	0.04	-0.03	-0.03	0.17**	-0.20**	0.03
Problem-solving	**0.02**	**0.03**	**0.02**	**-0.07****	**-0.06****	**0.08****	**-0.05***	**0.03**
quality circles	0.02	0.05*	0.01	-0.03	-0.01	0.01	-0.06**	0.03
briefing groups	0.01	-0.01	0.02	-0.08**	-0.09**	0.11**	-0.02	0.02
Top-Down	**0.045**	**0.07****	**0.1****	**0.05***	**0.08****	**0.07****	**-0.22****	**-0.07****
systematic use of management chain to communicate	0.02	0.03	0.04	-0.02	-0.05*	0.09**	-0.08**	0.01
share information about investment plans	0.03	0.03	0.08**	0.05*	0.07**	-0.01	-0.11**	-0.04
collect information on productivity	0.05*	0.08**	0.08**	0.07**	0.15**	0.08**	-0.27**	-0.11**
Decentralizing	**0.01**	**0.04**	**0.06***	**-0.02**	**-0.1****	**0.12****	**-0.08****	**0.01**
regular meetings between senior management and all workforce	0.01	0.06*	0.03	-0.01	-0.05*	0.023	-0.003	-0.02
suggestion schemes	0.01	0.01	0.06**	-0.03	-0.1**	0.16**	-0.12**	0.04
ALL	**0.038**	**0.06***	**0.07****	**-0.024**	**-0.050***	**0.17****	**-0.22****	**0.02**

Note 1: ** Significance at 1%, * Significance at 5%.

Table 3. Name and Description of the dependent and explanatory variables

Variable	*Description*
	Dependent Variables
Rewarding	Number of rewarding practices used in the workplace: profit-related pay scheme and share ownership scheme
Problem-solving	Number of problem-solving practices used in the workplace: quality circles and briefing groups
Top-down	Number of the top-down practices used in the workplace: systematic use of management chain to communicate; share information about investment plans; and collect information on productivity
Decentralizing	Number of decentralizing practices used in the workplace: regular meetings between senior management and all workforce, and suggestion schemes
All	Number of HRM practices in use in the workplace. Sum of rewarding, problem-solving, top-down and decentralizing practices used in the workplace
	Independent variables
Size	Logarithm of the number of employees
Sqsize	Logarithm of the squared number of employees
Foreign	0 if the workplace is UK owned (including 50/50), 1 if the workplace is foreign owned
Group	1 if the workplace is part of a multi-establishment organization / a Group, 0 if it is a single independent workplace
Advice	1 if the workplace sought advice on HRM from consultants, 0 otherwise
Association	1 if the workplace is member of Employers' Association, 0 otherwise
International	1 if the most significant market is international, 0 if local or national are more important markets
Local	1 if most significant market is local, 0 if the national or international are more important markets
Mproduct	0 if the workplace has one single product, 1 if the workplace has multiple products
Science	1 if the workplace is active in a science-based manufacturing activities i.e. pharmaceutical, electrical and optical equipment, 0 otherwise
Product-eng	1 if the workplace is active in product-engineering manufacturing activities i.e. machinery and equipment, 0 otherwise

Complex	1 if the workplace is active in complex-product manufacturing activities i.e. transport equipment, 0 otherwise
Fundamental	1 if the workplace is active in fundamental-process manufacturing activities i.e. chemicals, except pharmaceuticals, 0 otherwise
Continuous	1 if the workplace is active in continuous-process manufacturing activities i.e. food, textiles, leather, wood, pulp and paper, publishing and printing, fabricated metal, other non-metallic mineral, other manufacturing, 0 otherwise
Serv. dominated	1 if the workplace is active in supplier-dominate service activities i.e. construction, hotels and restaurants, public administration, education, health, other social and personal services, 0 otherwise
Serv. Scale	1 if the workplace is active in a scale-intensive service activities i.e. wholesale, transport, storage and distribution, and electricity, gas and water supply, 0 otherwise
Serv. technology	1 if the workplace is active in a technology-intensive service activities i.e. real state and business services and R&D activities and financial intermediation, 0 otherwise
Year	0 if 1990, 1 if 1998
Ysize	Year * Size
Ysqsize	Year * Sqsize
Yforeign	Year * Foreign
Ygroup	Year * Groups
Yadvice	Year * Advice
Yassociation	Year * Association
Yinternational	Year * International
Ylocal	Year * Local
YMproduct	Year * Mproduct

Table 4. Descriptive Statistics of the Dependent Variables

	All	Problem-solving	Top-down	Decentralizing	Rewarding
All	1				
Problem-solving	0.65**	1			
Top-down	0.75**	0.30**	1		
Decentralizing	0.64**	0.27**	0.29**	1	
Rewarding	0.63**	0.22**	0.30**	0.20**	1
Mean	4.51	0.97	1.9	0.79	0.85
Std	2.2	0.77	0.97	0.76	0.77
Min	0	0	0	0	0
Max	9	2	3	2	2

Note 1: *** Significance at 1%, ** Significance at 5%; * Significance 10%
Note 2: 1870 observations

Table 5. Descriptive Statistics of the Independent Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Size (Ln)	1																
2	Sqsize	0.99**	1															
3	Foreign	0.11**	0.11**	1														
4	Group	0.25**	0.24**	0.24**	1													
5	Advice	0.16**	0.16**	0.10**	0.01	1												
6	Association	0.09**	0.09**	0.07**	0.07**	0.06**	1											
7	International	0.22**	0.21**	0.21**	0.02	0.06*	0.08**	1										
8	Local	0.05*	0.06*	-0.02	-0.06**	0.04	0.01	-0.52**	1									
9	Mproduct	0.03	0.03	0.01	0.08**	0.04	-0.00	0.05*	-0.05*	1								
10	Fundamental	0.09**	0.08**	0.06**	0.02	0.00	0.01	0.07**	0.03	0.03	1							
11	Science	0.12**	0.12**	0.12**	0.05*	-0.04	0.09**	0.25**	-0.07**	0.07**	-0.04	1						
12	Complex	0.20**	0.22**	0.03	0.04	0.05*	0.10**	0.16**	-0.05*	0.01	-0.02	-0.04	1					
13	Product-eng	0.05*	0.05*	0.05*	0.02	-0.01	0.12**	0.15**	-0.03	0.03	-0.03	-0.05*	-0.031	1				
14	Continuous	0.10**	0.09**	0.03	-0.04	-0.01	0.02	0.10**	0.18**	-0.02	-0.07**	-0.13**	-0.079**	-0.10**	1			
15	Serv. scale	-0.03	-0.05*	-0.06*	0.21**	-0.07**	-0.02	-0.20**	-0.10**	0.04	-0.09**	-0.16**	-0.100**	-0.12**	-0.32**	1		
16	Serv. dominated	-0.26**	-0.25**	-0.08**	-0.22**	-0.07**	-0.02	-0.14**	-0.02	-0.13**	-0.07**	-0.13**	-0.078**	-0.10**	-0.25**	-0.32**	1	
17	Serv. technology	-0.00	0.01	-0.02	-0.05*	0.17**	-0.14**	-0.04	0.03	0.04	-0.07**	-0.11**	-0.071**	-0.09**	-0.23**	-0.29**	-0.23**	1
	Mean	5.04	26.88	0.14	0.75	0.17	0.19	0.23	0.3	0.57	0.02	0.06	0.02	0.04	0.20	0.29	0.2	0.17
	Std. Deviation	1.2	13	0.35	0.44	0.38	0.4	0.42	0.46	0.5	0.14	0.24	0.15	0.19	0.40	0.45	0.4	0.38
	Min	3.22	10.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Max	10.27	105.56	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1: *** Significance at 1%, ** Significance at 5%; * Significance 10%

Note 2: 1870 observations

Table 6. Explaining the level of use of *All* HRM practices, Poisson regression.

	Pooled	Manuf.	Serv.
Size	0.28***	0.47***	0.32***
	[0.08]	[0.05]	[0.10]
Sqsize	-0.018***	-0.029***	-0.0270***
	[0.006]	[0.004]	[0.007]
Foreign	-0.09	-0.003	-0.27***
	[0.07]	[0.06]	[0.05]
Group	0.43***	0.21***	0.52***
	[0.06]	[0.06]	[0.09]
Association	-0.13**	-0.09	-0.16**
	[0.05]	[0.0869]	[0.07]
Advice	0.19**	0.06	0.26***
	[0.08]	[0.06]	[0.08]
International	0.005	0.02	-0.11
	[0.05]	[0.06]	[0.09]
Local	0.058	-0.24**	0.01
	[0.04]	[0.10]	[0.06]
Mproduct	0.14***	0.04**	0.21***
	[0.04]	[0.02]	[0.03]
Ysize	0.08***	0.10***	0.06*
	[0.0202]	[0.04]	[0.03]
Ysqsize	-0.01**	-0.01	-0.002
	[0.003]	[0.006]	[0.002]
Yforeign	-0.07	-0.09*	0.07
	[0.06]	[0.05]	[0.12]
Ygroup	-0.07	-0.07	-0.11
	[0.06]	[0.07]	[0.13]
Yassociation	0.15**	0.06	0.21**
	[0.07]	[0.13]	[0.09]
Yadvice	-0.12	-0.003	-0.18*
	[0.09]	[0.08]	[0.1]
Yinternational	-0.05	-0.13*	0.13
	[0.07]	[0.07]	[0.13]
Ylocal	0.01	-0.07	0.05
	[0.07]	[0.09]	[0.1]
YMproduct	-0.08***	-0.1***	-0.13***
	[0.03]	[0.02]	[0.03]
Fundamental	0.06***	0.06***	
	[0.01]	[0.01]	
Science	0.12***	0.11***	
	[0.01]	[0.01]	
Complex	0.19***	0.15***	
	[0.03]	[0.01]	
Product-eng	-0.02***	0.01	
	[0.006]	[0.01]	
Serv. scale	0.06***		0.04***
	[0.02]		[0.01]
Serv. dominated	-0.1***		-0.11***
	[0.02]		[0.004]
Serv. technology	0.02		
	[0.03]		
Intercept	0.06	-0.40**	-0.01

	[0.26]	[0.16]	[0.36]
N. Observ.	1870	640	1230
Log likelihood	-3872.3	-1270.0	-2569.7
Wald chi2	661.64***	322.97***	491.3***
df	26	23	21

Note 1: Standard errors between parentheses

Note 2: *** Significance at 1%, ** Significance at 5%; * Significance 10%

Note 3: Reference category: continuous-process manufacturers in regressions with pool data and manufacturing separately; technology-intensive services in regression with service data separately.

Table 7. Explaining the level of use of *Problem-solving*, *Top-down*, *Decentralizing* and *Rewarding* practices, pooled data, Poisson regressions.

	Problem-solving	Top-down	Decentralizing	Rewarding
Size	0.18	0.24**	0.33**	0.46***
	[0.11]	[0.11]	[0.17]	[0.12]
Sqsize	-0.01	-0.01**	-0.02	-0.03***
	[0.01]	[0.01]	[0.01]	[0.01]
Foreign	0.06	-0.06	0.07	-0.60***
	[0.06]	[0.08]	[0.09]	[0.06]
Group	0.39***	0.28***	0.49***	0.85***
	[0.13]	[0.05]	[0.13]	[0.16]
Association	-0.21**	-0.05	-0.32**	-0.03
	[0.10]	[0.06]	[0.14]	[0.11]
Advice	0.16**	0.14**	0.35***	0.13
	[0.08]	[0.06]	[0.08]	[0.19]
International	0.01	0.03	-0.01	-0.05
	[0.06]	[0.05]	[0.07]	[0.11]
Local	0.13	0.05	0.02	0.013
	[0.11]	[0.06]	[0.11]	[0.08]
Mproduct	0.11	0.14***	0.10	0.20***
	[0.07]	[0.05]	[0.08]	[0.08]
Ysize	0.16***	0.09***	0.01	0.02
	[0.05]	[0.02]	[0.04]	[0.09]
Ysqsize	-0.01	-0.01***	-0.002	-0.002
	[0.01]	[0.003]	[0.01]	[0.01]
Yforeign	-0.17***	-0.04	-0.14**	0.18**
	[0.05]	[0.08]	[0.07]	[0.09]
Ygroup	-0.29*	-0.03	-0.07	0.17
	[0.17]	[0.03]	[0.15]	[0.23]
Yassociation	0.27**	0.02	0.4**	0.1
	[0.13]	[0.08]	[0.16]	[0.13]
Yadvice	-0.01	-0.08	-0.24***	-0.17
	[0.09]	[0.07]	[0.08]	[0.26]
Yinternational	-0.04	-0.08	-0.07	0.05
	[0.11]	[0.06]	[0.09]	[0.14]
Ylocal	-0.07	-0.02	0.20	-0.03
	[0.12]	[0.07]	[0.137]	[0.11]
YMproduct	-0.07	-0.09	-0.03	-0.14
	[0.08]	[0.06]	[0.07]	[0.11]
Fundamental	0.085***	-0.02***	0.14***	0.16***
	[0.02]	[0.007]	[0.02]	[0.0253]
Science	0.15***	0.01	0.33***	0.14***
	[0.02]	[0.01]	[0.02]	[0.02]
Complex	0.14*	0.13***	0.46***	0.11***
	[0.08]	[0.01]	[0.05]	[0.03]
Product-eng.	-0.22***	0.04***	0.11***	-0.09***
	[0.02]	[0.01]	[0.02]	[0.02]
Serv. scale	0.11***	-0.10***	0.28***	0.21***
	[0.02]	[0.03]	[0.06]	[0.03]
Serv. dominated	0.07***	-0.26***	0.17**	-0.19***
	[0.02]	[0.03]	[0.07]	[0.06]
Serv technology	0.08***	-0.20***	0.19***	0.30***

	[0.01]	[0.03]	[0.05]	[0.06]
Intercept	-1.33***	-0.45	-1.93***	-2.50***
	[0.35]	[0.32]	[0.48]	[0.39]
N. Observ.	1870	1870	1870	1870
Log likelihood	-2181.7	-2728.2	-2013	-1971.6
Wald chi2	172.2***	388.7***	216.3***	468.3***
df	26	26	26	26

Note 1: Standard errors between parentheses
Note 2: *** Significance at 1%, ** Significance at 5%; * Significance 10%
Note 3: Reference category: continuous-process manufacturers.

Table 8. Explaining the level of use of *Problem-solving*, *Top-down*, *Decentralizing* and *Rewarding* practices, in manufacturing and services separately, Poisson regressions.

	Problem-solving		Top-down		Decentralizing		Rewarding	
	Manuf.	Serv.	Manuf.	Serv.	Manuf.	Serv.	Manuf.	Serv.
Size	0.50***	0.29	0.34***	0.21	0.86***	0.32	0.47*	0.66***
	[0.07]	[0.21]	[0.06]	[0.13]	[0.23]	[0.25]	[0.26]	[0.20]
Sqsize	-0.02**	-0.03	-0.02***	-0.01	-0.06***	-0.03	-0.03	-0.06***
	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]	[0.02]	[0.02]
Foreign	0.14**	-0.08***	0.024	-0.23**	0.22***	-0.16	-0.54***	-0.77***
	[0.06]	[0.02]	[0.08]	[0.09]	[0.07]	[0.12]	[0.06]	[0.06]
Group	-0.04	0.52***	0.15**	0.371***	0.04	0.69***	1.0***	0.69**
	[0.11]	[0.15]	[0.06]	[0.004]	[0.14]	[0.14]	[0.13]	[0.28]
Association	-0.004	-0.45***	-0.09	0.02	-0.23	-0.48***	-0.06	0.018
	[0.11]	[0.06]	[0.08]	[0.06]	[0.20]	[0.15]	[0.11]	[0.28]
Advice	0.18***	0.12	0.023	0.22***	0.15*	0.47***	-0.13	0.24
	[0.03]	[0.1]	[0.08]	[0.04]	[0.08]	[0.04]	[0.17]	[0.23]
International	0.02	-0.1	0.06	-0.10*	0.05	-0.26***	-0.11*	0.021
	[0.07]	[0.07]	[0.06]	[0.06]	[0.08]	[0.01]	[0.06]	[0.3]
Local	-0.60	0.05	-0.30***	0.07	0.07	-0.10	-0.12	-0.02
	[0.40]	[0.13]	[0.1]	[0.08]	[0.23]	[0.09]	[0.14]	[0.16]
Mproduct	-0.0279	0.21**	0.10***	0.14	-0.09	0.24***	0.07	0.31***
	[0.0507]	[0.09]	[0.03]	[0.12]	[0.08]	[0.08]	[0.08]	[0.03]
Ysize	0.17	0.116*	0.08***	0.11***	-0.03	0.001	0.27**	-0.14*
	[0.12]	[0.0684]	[0.02]	[0.03]	[0.1]	[0.02]	[0.13]	[0.08]
Ysqsize	-0.02	-0.002	-0.003	-0.01	-0.001	0.004	-0.02*	0.02***
	[0.02]	[0.01]	[0.003]	[0.01]	[0.02]	[0.005]	[0.01]	[0.01]
Yforeign	-0.19	-0.09*	-0.03	0.05	-0.15	0.06	0.05	0.37***
	[0.14]	[0.04]	[0.10]	[0.16]	[0.18]	[0.15]	[0.12]	[0.08]
Ygroup	0.15	-0.42**	-0.08**	-0.07***	0.098	-0.23	-0.62**	0.55***
	[0.16]	[0.21]	[0.04]	[0.03]	[0.11]	[0.24]	[0.25]	[0.07]
Yassociation	-0.08	0.56***	0.08	-0.05	0.07	0.63***	0.12	0.05
	[0.12]	[0.12]	[0.09]	[0.09]	[0.30]	[0.17]	[0.26]	[0.27]
Yadvice	-0.02	0.02	0.03	-0.15***	-0.134	-0.346***	0.05	-0.28
	[0.08]	[0.10]	[0.11]	[0.05]	[0.14]	[0.1]	[0.31]	[0.33]
Yinternational	-0.14	0.12	-0.16***	0.13	-0.18	0.27***	0.04	0.02
	[0.15]	[0.14]	[0.04]	[0.09]	[0.13]	[0.05]	[0.07]	[0.34]
Ylocal	0.72**	0.02	-0.09	-0.04	-14.48***	0.31***	0.13	0.002
	[0.32]	[0.12]	[0.08]	[0.11]	[0.8]	[0.10]	[0.36]	[0.21]
YMproduct	0.08	-0.17**	-0.20***	-0.04	0.13	-0.16**	-0.23	-0.21
	[0.08]	[0.08]	[0.05]	[0.11]	[0.09]	[0.06]	[0.19]	[0.13]
Fundamental	0.04		-0.01***		0.14***		0.20***	
	[0.03]		[0.004]		[0.03]		[0.03]	
Science	0.11***		0.02		0.31***		0.18***	
	[0.02]		[0.01]		[0.04]		[0.03]	
Complex	-0.04		0.15***		0.39***		0.13**	
	[0.05]		[0.01]		[0.05]		[0.07]	
Product-eng	-0.21***		0.07***		0.12***		-0.04	
	[0.02]		[0.01]		[0.03]		[0.04]	
Serv. scale		0.01		0.09***		0.1***		-0.08
		[0.0283]		[0.01]		[0.0004]		[0.07]
Serv.		-0.0204		-0.06***		-0.0003		-0.46***

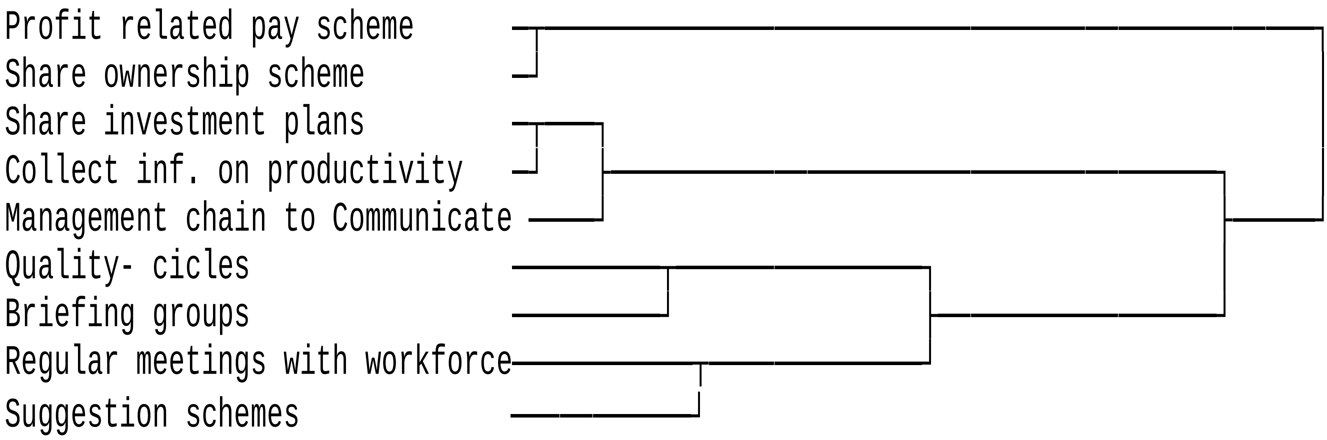
dominated		[0.0148]		[0.02]		[0.04]		[0.02]
Intercept	-2.29***	-1.38**	-0.59***	-0.65	-3.29***	-1.72**	-2.74***	-2.51***
	[0.19]	[0.61]	[0.19]	[0.41]	[0.58]	[0.73]	[0.80]	[0.63]
N. Observ.	640	1230	640	1230	640	1230	640	1230
Log likelihood	-719.6	-1445.3	-938.1	-1778.3	-652.6	-1340.9	-654.4	-1304.1
Wald chi2	110.1***	106.1***	141.8***	259.2***	764.0***	176.9***	112.4***	365.2***
df	23	21	23	21	23	21	23	21

Note 1: Standard errors between parentheses

Note 2: *** Significance at 1%, ** Significance at 5%; * Significance 10%

Note 3: Reference category: continuous-process in manufacturing regression; and technology-intensive services in services regression.

Figure 1. Results of the Hierarchical Cluster Analysis of HRM practices: Dendrogram using Average Linkage (Between Groups)



Note: 1870 observations

APPENDIX

Table A1. Significance of differences in the use of *All*, problem-solving, top-down, decentralizing and rewarding practices across technological learning environments.

		Fundamental	Science	Complex	Product-eng.	Serv. scale	Serv. dominated	Serv. technology	Continuous (ref.)
Fundamental	All	**Separately**	NS	**	**	NS	**	**	**
	Problem-solving		NS	NS	**	NS	**	NS	*
	Top-down		NS	**	NS	**	**	**	NS
	Decentralizing		NS	**	**	NS	**	NS	*
	Rewarding	**Pooled**	NS	NS	**	**	**	NS	*
Science	All	**	**Separately**	NS	**	NS	**	NS	**
	Problem-solving	**		NS	**	NS	*	NS	**
	Top-down	**		**	NS	NS	**	**	NS
	Decentralizing	**		NS	NS	NS	**	NS	**
	Rewarding	NS	**Pooled**	NS	NS	*	**	NS	**
Complex	All	**	**	**Separately**	**	NS	**	**	**
	Problem-solving	NS	NS		**	NS	NS	NS	*
	Top-down	**	**		**	**	**	**	**
	Decentralizing	**	**		**	NS	**	**	NS
	Rewarding	NS	NS	**Pooled**	NS	NS	**	NS	NS
Product-eng.	All	**	**	**	**Separately**	**	**	NS	NS
	Problem-solving	**	**	**		**	*	**	*
	Top-down	**	**	**		NS	**	**	NS
	Decentralizing	NS	**	**		*	NS	NS	NS
	Rewarding	**	**	**	**Pooled**	**	*	**	NS
Serv. scale	All	NS	NS	**	**	**Separately**	**	**	**
	Problem-solving	NS	NS	NS	**		NS	NS	**
	Top-down	**	**	**	**		**	**	NS
	Decentralizing	**	NS	**	**		**	NS	**
	Rewarding	**	*	*	**	**Pooled**	**	NS	**
Serv. dominated	All	**	**	**	**	**	**Separately**	**	**
	Problem-solving	NS	**	NS	**	NS		NS	NS
	Top-down	**	**	**	**	**		**	**
	Decentralizing	NS	**	**	NS	**		*	NS
	Rewarding	**	**	**	NS	**	**Pooled**	**	**
Serv. technology	All	NS	**	**	NS	**	**	**Separately**	*
	Problem-solving	NS	**	NS	**	NS	NS		**
	Top-down	**	**	**	**	**	**		**
	Decentralizing	NS	**	**	NS	**	NS		**
	Rewarding	**	**	**	**	**	**	**Pooled**	**
Continuous (reference)	All	**	**	**	**	**	**	NS	**Separately**
	Problem-solving	**	**	**	**	**	**	**	
	Top-down	**	NS	**	**	**	**	**	
	Decentralizing	**	**	**	**	**	**	**	
	Rewarding	**	**	**	**	**	**	**	**Pooled**

Note 1: ** Significance at 1% and at 5%; * Significance 10%, NS Non-significant

Note 2: The right hand side of the table refers to differences in Model with Pooled data and the left hand side of the table refers to differences in Model in manufacturing and services separately.