New HRM Practices, Complementarities, and the Impact on Innovation Performance

Keld Laursen and Nicolai J. Foss

Department of Industrial Economics and Strategy,
Copenhagen Business School, Howitzvej 60, 2000 Frederiksberg, Denmark
E-mail: kl.ivs@cbs.dk, njf.ivs@cbs.dk

3rd draft, this version: 3 May 2000

Acknowledgements
We are grateful to Allan Næs Gjerding, Frank Skov Kristensen, Ned Lorenz, Bengt-Åke Lundvall, Ian Miles, Torben Pedersen and Ammon Salter and the participants the in 3rd Applied Econometrics Conference, Alicante, Spain, 20 –21 April 2000 for comments made on earlier versions of this paper. In addition, wish to thank the participants in the DISKO project for allowing us to use the data applied in this paper. In particular, we wish to thank the persons responsible for carrying out the survey, including project leader Bengt-Åke Lundvall, Allan Næs Gjerding, Kenneth Jørgensen, Frank Skov Kristensen, Reinhard Lund, Poul Thøis Madsen, Peter Nielsen and Søren Nymark.

New HRM Practices, Complementarities and the Impact on Innovation Performance

Abstract

Although organisational structure has sometimes been mentioned in evolutionary economics as well as in the innovation literature as a possible determinant of innovation performance, little systematic theoretical and empirical work exist on this issue. In this paper, we take our theoretical point of departure in recent work in organisational economics on *systems* of human resource management practices. We put and develop the argument that just as complementarities between new HRM practices positively influence financial performance, they will also positively influence innovation performance. We examine this overall hypothesis by estimating an empirical model of innovation performance, using data from a Danish survey of 1900 business firms. Using principal components analysis we identify two HRM systems which are conducive to innovation. The first is one in which all of our nine HRM variables matter (almost) equally for the ability to innovate. The second system, which is found to be conducive to innovation is dominated by performance related pay and to some extent by firm-internal training. Of our total of nine sectors we find that the four manufacturing sectors correlate with the first system, while also firms located in ICT intensive service sectors are (however weakly) associated with the first system. Firms belonging to the wholesale trade sector tend to be associated with the second system.

JEL classification*:*
C25, D23, O32

Keywords
Innovation, human resource management practices, organisational complementarities, evolutionary economics.

I. Introduction: New HRM Practices and Innovation

The ongoing re-structuring of management practices designed to cope with an increasingly complex and rapidly changing knowledge-based economy has received increasing attention from scholars from a diversity of disciplines and fields (Bowman and Singh, 1993; Huselid, 1995; Guest, 1997; Zenger and Hesterly, 1997). In particular, much attention has been given to the restructuring of the employment relation in the form of changed human resource management (henceforth, "HRM") practices that has accompanied the emergence of firms specialised to competing in dynamic, information-rich environments. These practices encompass various types of team-based organisation, continuous (often internal and team-based) learning, decentralisation of decision rights and incentives, systems for mobilising employee proposals for improvements, quality circles, emphasis on internal knowledge dissemination, etc. (Lado and Wilson, 1994; Zenger and Hesterly, 1997; Mendelson and Pillai, 1999).

While many of these new practices may not, strictly speaking, be entirely novel, some of the broad generalisations about new HRM practices refer to trends that appear to be truly recent. Thus, new HRM practices appear to follow a steep diffusion curve; they tend to be adopted in a system-like manner rather than as individual components; and they tend to be associated with high innovation performance (Mendelson and Pillai, 1999). It is these "stylised facts" that we try to theoretically and empirically address and substantiate in this paper.

The increased attention paid to new HRM practices has been particularly prevalent in the fields of strategic management, human resource management, and, increasingly, the economics of organisation. For example, strategy scholars have argued that human resources are significant strategic levers, which are particularly likely to the sources of sustained competitive advantage and that HRM practices should therefore be central to strategy (Barney, 1991; Lado and Wilson, 1994; Barney, 1995). A reason for this is the system-like — or, in the terminology that we shall make use of, "(Edgeworth) complementary" — way in which HRM practices may connect. The complementary nature of many of the elements of (formal and informal) organisational structure has been examined in an emerging important literature in organisational economics (notably Milgrom and Roberts, 1990; Aoki and Dore, 1994; Milgrom and Roberts, 1995; Holmström and Roberts, 1998). Insights from this literature have made some impact in the human resource management field (Baron and Kreps, 1999).

Although the connection between internal organisation issues and innovativeness has certainly never been neglected in the innovation and evolutionary economics literature — after all, the increasing bureaucratisation of the R&D function was a key theme in Schumpeter's later work — it is also fair to say that these literatures are characterised by relatively scant attention being paid to new (complementary) HRM practices and on how they influence innovation performance.[1] Something similar may be said of the HRM

[1] The clear exception is constituted by some scholars' interest in Japanese economic organisation and how this connects to innovativeness. Thus, Freeman (1988: 335) explicitly notes how in "Japanese management, engineers and workers grew accustomed to thinking of the entire production process as a system and of thinking in an integrated way about product design and process design," and he makes systematic reference to quality management, horizontal information flows, and other features of new HRM practices. One could also construct an argument that already the concern with horizontal information flows in the late 1960s Project SAPPHO demonstrates a long-standing awareness of the relation between HRM practices and innovation

literature; here, too, there is a lack of theoretical and empirical treatment of how new HRM practices impact on innovation performance.[2] In sum, there is clearly in a number of fields and disciplines an emerging theoretical and empirical understanding of how HRM practices and complementarities between these impact on productivity and, in turn, on financial performance, but that understanding needs to be extended to also encompass innovation performance. To do this is the purpose of the paper. Thus, we shall argue and empirically demonstrate that new HRM practices and complementarities between these impact on *innovation performance,* that is, on future competitive advantages.

As far as we know, this is the first major empirical examination of the link between innovation performance and complementary new HRM practices. Thus, Gjerding (1997), Michie and Sheehan (1999), and Mendelson and Pillai (1999), while examining the HRM-innovation performance link, do not incorporate considerations of complementarity. Lorenz (1998) analyses complementarities between the use of new HRM practices and so-called new pay policies, but does not include a measure of performance in the analysis. And Ichniowski, Shaw and Prennushi (1997), while discussing the complementarity-performance (productive efficiency) link, do not deal with innovation performance. As opposed to this, we link together complementarity and innovation performance. Furthermore, in our analysis the HRM "systems" (a particular combination of HRM practices) emerge out of an analysis (principal components analysis), while Ichniowski, Shaw and Prennushi (1997), assume their four different systems from the outset. Arguably, Ichniowski, Shaw and Prennushi (1997) are able to define fine-grained controls since they focus on HRM complementarities found in steel finishing lines only. However, the drawback is that the conclusions drawn do not concern the entire economy as such. In contrast, we test hypotheses that articulate the HRM-innovation link on a large Danish data set, the DISKO data base, which contains cross-sectional information on the HRM practices and innovation performances of 1,900 Danish firms in both manufacturing and non-manufacturing industries.

We contribute to several literatures. Thus, our finding that complementarity obtains in HRM practices provides further empirical support for theoretical work on complementarity in organisational economics and elsewhere. Our investigation of the links between complementary HRM practices and innovation performance contributes to the strategy content literature as well as to the innovation literature. However, we see the present paper as most directly linking up with work in evolutionary economics and innovation studies. Much of this work has had an aggregate focus in which the internal organisation of the firm has been left out, and where interest has primarily centred on issues such as appropriability, firm size, market structure, complementary assets, etc. as determinants of innovation performance. The findings in this paper may be taken as an indication of the importance of internal factors for the understanding of innovation (while not denying the importance of other factors).

The design of the paper is the following. We begin by reviewing recent work on complementarities in organisational economics. Complementarities allow us to better understand the "systemic" quality that characterise technologies and the internal

---

performance. However, exceptions may always be found, and we think it is a fair judgement that other determinants of innovation performance, such as appropriability, market structure, control of complementary asserts, etc. have played bigger roles in the literatures.

[2] For example, Guest's (1997) programmatic discussion does not mention innovation as a relevant performance variable.

organisation of firms in many contexts. Moreover, the notion of complementarity is helpful for understanding how performance is influenced by such systemic'ness. Thus, we argue that complementarities allow us to understand the clustering of HRM practices in firms. Moreover, complementarities between HRM practices influence not only the firm's profits, but also, we argue, its innovation performance ("*Complementarity, New HRM Practices and Innovation Performance: Theoretical Considerations*"). We then specify a simple model that allows us to test these ideas on the data set represented by the DISKO database. We apply a probit model as the relevant means of estimation. Using principal-components analysis, we identify two HRM systems that are both conducive to innovation. The first is one in which all of nine HRM variables matter (almost) equally for the ability to innovate. The second system is dominated by performance related pay and to some extent by firm-internal training as well. Hence, we conclude that the application of HRM practices do matter for the likelihood of a firm being an innovator. Furthermore, since the two HRM systems were strongly significant in explaining innovation performance, while only two individual practices (out of nine) are found to be significant, we find support for the hypothesis of the importance for innovation performance of complementarities between certain HRM practices within each of the two HRM systems ("*Empirical Analysis*").

II. Complementarity, New HRM Practices and Innovation Performance: Theoretical Considerations

The HRM-Innovativeness Link: a Black Box?

Contributions that not only mention but actually theoretically and empirically address the link between HRM practices and innovation performance are surprisingly few in number. To be sure, there is a large, somewhat heterogeneous, literature on the management of innovation and technology. However, much of this literature is largely taken up with strategy issues connected to the exogenous dynamics of technology (e.g., technology life cycles), large-scale organisational issues, and questions relating to appropriability (e.g., Tushman and Moore, 1988). Of course, beginning with Burns and Stalker (1961) the organisational behaviour field has stressed the link between "organic" organisational structures and innovation performance. A recent stream of pertinent organisational behaviour research has been prompted by March's (1991) distinction between "exploration" and "exploitation."

However, it is not too unfair to say that more precise theoretical identifications of the mechanisms underlying the hypothesised links between HRM practices and innovativeness are virtually non-existing. This is true of both the technology management and the organisational behaviour literatures. To offer further illustrative examples, Baron and Kreps' (1999) recent economics inspired treatise on human resource management does not treat innovativeness as a relevant performance variable. Michie and Sheehan (1999), while empirically finding a link between HRM practices and innovation performance, do not offer a theory of this link. Virtually all of the economics literature on the firm level determinants of innovation have dealt with issues such as the famous debates on the relation between firm size and innovation performance (Acs and Audretsch, 1988; Cohen and Klepper, 1996). The organisational factors which may mediate any such relations have largely been black-boxed. Finally, while the emerging evolutionary economics literature on the firm (e.g., Kogut and Zander, 1992; Dosi and Marengo, 1994; Henderson, 1994; Granstrand, Patel and Pavitt, 1997; Pavitt, 1998; Laamanen and Autio, 2000) has certainly stressed complementarities between diverse technologies and the learning this may stimulate, the organisational requirements that stimulating and reaping benefits from such complementarities may demand have seldom been investigated in any detail.

In sum, therefore, while many contributors have noted a link between new HRM practices and innovation performance, and while some contributions have stressed the link between complementary knowledge stocks and innovation performance, no contributions appear (as far as we know) to have put forward theoretical arguments asserting a link between complementary new HRM practices and innovation performance. However, as indicated, various literatures do contain ideas that are pertinent to the understanding of the link between HRM practices, complementarities between these and innovation performance. We briefly discuss such ideas in the following.

Complementarities

One of the most important strides forward in the economics of organisation during the last decade is the increasing use that has been made of the notion of Edgeworth complementarities (Milgrom and Roberts, 1990; Milgrom, Qian and Roberts, 1991; Aoki and Dore, 1994; Holmström and Milgrom, 1994 ; Milgrom and Roberts, 1995; Ichniowski, Shaw and Prennushi, 1997; Holmström and Roberts, 1998; Baron and Kreps, 1999). No doubt, the high priests of this movement have been Paul Milgrom and John Roberts. As they define it, complementarity between activities obtains if "… doing more of one thing increases the returns to doing (more of) the others" (Milgrom and Roberts, 1995: 181). Formally, this will be seen to closely correspond to mixed-partial derivatives of a pay-off function with standard assumptions about smoothness of this function. However, as Milgrom and Roberts argue, drawing on the mathematical field of lattice theory, the notion of complementarity is not wedded to the conventional differentiable framework.[3] Mathematically, complementarity between a set of variables obtains when a function containing the relevant variables as arguments is supermodular.[4]

There are many reasons why we think that scholars in a diverse set of fields, including evolutionary economists, technology studies and organisational behaviour, should take an interest in the notion of complementarities (and the associated formalisms). On the most fundamental level, it provides an understanding of those systemic features of technologies that have traditionally interested these scholars (e.g., national systems of innovation, technology systems).[5] The other side of the coin is that complementarity is an important source of path-dependence: Successful change has to involve many, perhaps all, relevant variables of a system and "involve" them in certain ways. This also helps

[3] In terms of the intuition of the notion of complementarity, the notion represents a strong possible conceptualisation of notion such as "synergy," "(organisational) fit," and "consistency" (Porter, 1996; Baron and Kreps, 1999).

[4] Given a real-valued function f on a lattice X, f is supermodular and its arguments are complements if for any x and y in X, $f(x) - f(x \wedge y) \le f(x \vee y) - f(y)$ (Milgrom and Roberts, 1995: 183). A lattice $(X, \ge)$ is a set (X) with a partial order $(\ge)$ with the property that for any x and y in X, there is a smallest element $(x \vee y)$ that is larger than x and y and largest element $(x \wedge y)$ that is smaller than both.

[5] On the method level, it should appeal that complementarities (and the underlying mathematical lattice theory) do not involve the drastic divisibility and concavity assumptions that have often been criticised by evolutionary economists (e.g., Nelson, 1980).

explaining why complementarities are an important source of self-propelled change (cf. Milgrom, Qian and Roberts, 1991), that is, "cumulative change."[6] Thus, notion of complementarity is helpful for understanding, for example, technological paradigms and national systems of innovation. At the level of the firm, the notion of complementarity may assist in the understanding of diversification patterns (Granstrand, Patel and Pavitt, 1997) — for example, it implies that firms will find most profitable new activities (or technologies) in areas that are complementary to newly increased activities (technologies). As we shall further argue, the notion of complementarity is also helpful for understanding the links between organisational variables — specifically, what is here called "new human resource management practices" — and innovation performance.

Complementarities and New HRM Practices

Although ideas on complementarity is applicable to virtually any social system, the paradigm case of Milgrom and Roberts' work on the subject is the basic redefinitions of strategies, organisation and management in manufacturing firms that have taken place during the last decades. This is sometimes conceptualised as a transition from a mass production system (or, Fordism) to a lean production system, the latter involving flexibility, trust-based relationships, speedy production and delivery, core competencies, etc. In Milgrom and Roberts' interpretation, the diverse characteristics of modern manufacturing are complementary parts in an interlocking system whose emergence has been prompted by fundamental changes in technology (IT, flexible machines) and tastes (broader product lines with more frequent product introductions).

A strongly simplified representation of Milgrom and Roberts' (1990) reasoning is to stipulate that a firm's revenues depend on the frequency with which it product innovates, α, and on the frequency of its process improvements, β: π (α, β). Following Milgrom and Roberts, we assume that π is supermodular in α and β. The costs of undertaking product innovations and process improvements depend on, for example, the level of training of the firm's workforce, the assignment of problem-solving rights to the shop floor, the use of teams, etc. – in short, a host of variables related to new HRM practices. For example, the lower the costs of increasing the training of the workforce, the more process improvements will result. We assume there are n HRM variables, $(\mu_1 \ldots, \mu_i, \ldots \mu_n)$.

We also assume that the cost of producing a particular level of innovations, ε are E (ε, s), where s is a crucial parameter which influences at least some of the cost-influencing variables in such a way that increasing s implies that the costs of increasing these variables are reduced. What might this parameter be? In Milgrom and Roberts (1990; 1995), there are actually two such (shift) parameters, which they take to represent the (increased) use of computer-aided design equipment and the (lower) costs of applying computer-numeric controlled machinery. In this context it is important to note that in our empirical analysis we take the exogenous shift for given, while focussing on the effects of such a shift. Whatever the specific rationale we may represent the costs of undertaking product innovations and process improvements as R $(\mu_1 \ldots, \mu_i, \ldots \mu_n; \lambda; \varepsilon)$. λ represents other possible costs of innovations and process improvements. Such costs might be related to the

[6] As Milgrom and Roberts (1995: 187) point out, a "… movement of a whole system of complementary variables, once begun, tends to continue," thus providing an aspect of the understanding of co-evolution.

external environment of firms in terms of costs of vertical disintegration[7], or to the fact that firms face different costs of innovating, due to differences in technological opportunities across sectors. We assume that (-*R*) is supermodular. This means that increasing μ_i reduces additional costs of undertaking product innovation or process improvements. Moreover, increasing *s* reduces the costs of increasing μ_i.

Since both π and *R* are supermodular, the overall objective function,

$$\Pi\ (\alpha, \beta; \mu_1 \ldots, \mu_i, \ldots \mu_n; \lambda; \varepsilon; s) = \pi\ (\alpha, \beta) - R\ (\mu_1 \ldots, \mu_i, \ldots \mu_n; \lambda) - E\ (\varepsilon, s), \quad (1)$$

will also be supermodular.[8] This implies that, for example, a reduction in the costs of transmitting information leads to an increase in the intensity of processing, storing and transmitting information, which in turn will give rise to more product innovation and process improvements and a greater use of new HRM practices**.** In other words, ideas on complementarity can account for what Mendelsson and Pillai (1999) call "high IQ organisations," that is, firms that combine a high level of innovativeness with widespread use of IT and new HRM practices. Moreover, these ideas help explaining why the emergence of such firms have primarily been prompted by the falling costs of processing information. However, it still remains to be explained why new HRM practices matter to innovation performance, that is, why (α, β) depend on ($\mu_1 \ldots, \mu_i, \ldots \mu_n$). Relatedly, it also remains to be explained why complementarity of new HRM practices matters to innovativeness.

Innovation, Complementarities and New HRM Practices

To repeat, "new HRM practices" is the overall label put on a host of contemporary changes in the organisation of the employment relation, referring to team-based organisation, continuous (often team-based) learning, decentralisation of decision rights and incentives, emphasis on internal knowledge dissemination, etc. While there may be strong financial performance effects, productivity effects and flexibility advantages of such new HRM practices — as documented by Huselid (1995), Ichniowski, Shaw, and Prennushi (1997) and Mendelsson and Pillai (1999), respectively — our main emphasis is on the impact on innovation performance, in particular, on product innovation.

New HRM practices can be conducive to innovative activity for a number of reasons. With respect to process innovations/improvements, one notable feature of many new HRM practices is that they increase decentralisation, in the sense that problem-solving rights are delegated to the shopfloor. Accomplished in the right way, this amounts to delegating rights in such a way that they are co-located with the pertinent knowledge, much of which is inherently tacit. In other words, increased delegation may better allow for the discovery and utilisation of local knowledge in the organisation, particularly when there are incentives in place that foster such discovery (Hayek, 1948; Jensen and Meckling, 1992). Indeed, much of the ability of Japanese firms to engage in ongoing, incremental process innovation turns on a successful co-location of problem rights and localised knowledge combined with appropriate pecuniary and non-pecuniary incentives (Aoki and Dore, 1994).

[7] In fact, Milgrom and Roberts (1995: 196) have experimented with extensions of their model, where they included increased vertical disintegration to the pattern of changes. This analysis is not, however, explicitly documented in the paper.

[8] Formally, this also requires that the feasible values of the choice variables, (α, β; $\mu_1 \ldots, \mu_i, \ldots \mu_n$; λ; ε), lie in a sublattice in R^{n+2}.

Relatedly, the increased use of teams that is an important component in the package of new HRM practices also means that better use can be made of local knowledge, leading to improvements in processes and perhaps also to minor product improvements. But teams can do something more, since they are often composed of different human resource inputs. In other words, teams often bring together knowledge that hitherto existed separately, potentially resulting in non-trivial process improvements (when teams are on the shop floor) or "new combinations" that lead to novel products (Schumpeter, 1912/1934)(when teams are in product development departments). Training of the workforce may be expected to be a force pulling in the direction of a higher rate of process improvements and possibly also product innovations, depending on the type, amount and quality of the relevant training. Generally, increased knowledge diffusion, for example, through job rotation, and increased information dissemination, for example, through IT, may also be expected to provide a positive contribution to the firm's innovation performance, for obvious reasons.

Thus, there are reasons to expect that the adoption of new HRM practices leads to increased innovation performance. Arguably, the adoption of a single such practice may provide a contribution to innovative performance. For example, rewarding shop floor employees for minor process improvements is likely to increase such incremental innovation activity, more or less regardless of the specific firm in which the reward system is implemented. However, other practices may not be expected to have significant impact on innovation performance, if implemented in isolation. At least to the extent that implementing new HRM practices is associated with extra effort or with disutility of changing to new routines, etc., employees will have to be somehow compensated. Thus, we would expect many new HRM practices to work well (in terms of both profits and innovation performance) only if accompanied with new, typically more incentive-based, remuneration schemes. Evidence appears to support this (Ichniowski, Shaw and Prennushi, 1997).

In general, we should on *a priori* grounds expect new HRM practices to be most conducive to innovation performance when adopted, not in isolation, but as a system of mutually reinforcing practices. The arguments in favour of this are relatively straightforward. For example, the benefits from giving shop floor employees more problem-solving rights will likely depend positively on the level of training of such employees. The converse is also likely to hold: employees may invest more in upgrading their skills if they are also given the extensive problem-solving rights (i.e., actually utilise those skills), particularly if they are given the right (intrinsic or extrinsic) motivation. Relatedly, rotation and job-related training may be complements in terms of their impact on innovative activity. All such practices are likely to be complements to various incentive-based remuneration schemes (whether based on individual, team or firm performance), profit sharing arrangements, and promotion schemes (Zenger and Hesterly, 1997).

In sum, while individual new HRM practices may be expected have some positive impact on innovation performance, theory would lead us to expect that because of complementarities between these practices, systems of HRM practices will be significantly more conducive to innovation than individual practices. In the following, we empirically examine these ideas.

III. Empirical Analysis

A. The Empirical Model

Based on the discussion above the rate of innovation may be specified as follows:

$$a = f(\beta_1 z, \beta_2 x). \tag{2}$$

Here, a is the level of innovation, β_1 and β_2 are parameter vectors, and z is a set of (exogenous) determinants of innovation, related to the application of human resource management practices, while x is a set of other variables explaining innovative performance across business firms. The variables included in the vector x, can be said to be standard variables in explaining innovation performance (Geroski, 1990; Kleinknecht, 1996). This model can be made operational in the following way:

$$A_i = \alpha SIZE_i + \chi SECT_i + \delta LINK_i + \phi EXREL_i + \varphi SUBSID_i + \eta_j HRMP_i^j + .. + \eta_n HRMP_i^n + \varepsilon_i, \tag{3}$$

where A_i expresses the firms' ability to innovate. If the firm in question is a non-innovator, the variable takes the value of 0, if the firm has introduced (in the period 1993-95) a product or service, new to the firm the value is 1, if the firm has introduced a product that is new in a Danish context over the period, the value is 2, while the value for this variable is 3 if the firm has introduced a product (or service) which is new to the world. Hence, only the final category qualifies for being an innovation in the strict sense of the word. Our sample includes 928 non-innovators, 728 firms that produced products/services that were new only to the firm itself, 125 firms that produced products/services that were new to the national market, while 103 firms introduced products/services that were new to the world.

As is common in studies aiming at explaining innovative performance (e.g. Geroski, 1990; Michie and Sheehan, 1999) we control for firm size (*SIZE*) and for sectoral affiliation (*SECT*). We include nine sector categories. For what concerns the sectoral classification, we apply the Pavitt taxonomy and the four corresponding sectors for manufacturing firms. For the service firms in our sample, we construct five additional sectors. Explanations of the sectoral classification that we apply may be found in Appendices 1 and 2 to this paper. As argued by Geroski (1990), such sectoral controls can be interpreted to capture differences in technological opportunities facing firms located in different sectors.

Other control variables include whether or not the firm in question has increased its vertical interaction with other firms, being it either upstream or downstream (*LINK*). This variable is supposed to pick up the effect of interactions with suppliers and users for innovation performance as stressed by e.g. Lundvall (1988) and von Hippel (1988).

EXREL expresses whether the firm has increased its interaction with knowledge institutions, including technical support institutions, consultancies or with universities. In this context it can be noted that Brouwer and Kleinknecht (1996) found that firms which had consulted an innovation centre were more likely to innovate than were other firms.

Although both *LINK* and *EXREL* concern whether the firms have increased their external linkages, we interpret these variables more broadly as measuring the strength of the respective linkages. The reason for this is that we argue that respondents who have strong linkages with external partner are very likely to answer that they have *increased* interaction with partners. Finally, we control for whether or not the firm is a subsidiary of a larger firm. The effect of this variable is, however, ambiguous. On the one hand, firms with centralised R&D departments might not wish their subsidiaries to be innovative, as such a procedure could be seen as hampering economies of scale in R&D. On the other hand, as argued by Harris and Trainor (1995), subsidiary firms might benefit from the larger resource base and experience of the parent firm. Some early empirical studies (e.g. Howells, 1984) found a negative effect of this variable on innovation performance, while more recent studies detected a positive effect (Harris and Trainor, 1995; Love, Ashcroft and Dunlop, 1996).

The variables $HRMP_i^{\,j}$ .. $HRMP_i^{\,n}$ are our new HRM variables, that is, those variables that are key to the analysis. We include nine binary variables pertaining to new HRM practices, which express whether firms apply (i) interdisciplinary workgroups, (ii) quality circles, (iii) systems for collection of employee proposals, (iv) planned job rotation, (v) delegation of responsibility, (vi) integration of functions, (vii) performance related pay, (viii) firm-internal training, and finally, whether or not the firm in questions uses (ix) firm-external training.

However, as argued earlier, work on complementarities suggest that HRM practices are more effective when they are applied in systems relative to when they are applied alone. Hence, we will estimate models where HRM practices enter the equation to be estimated in certain configurations or systems:

$$A_i = \alpha SIZE_i + \chi SECT_i + \delta LINK_i + \phi EXREL_i + \varphi SUBSID_i + \varpi_j HRMS_i^j + .. + \varpi_n HRMS_i^n + \varepsilon_i , \qquad (4)$$

where the notation is the same as in Equation (3). $HRMS_i^{\,j}$ .. $HRMS_i^{\,n}$ denote HRM systems, made up by configurations of our nine HRM practices.[9] Subsequently, we shall compare the estimations made, when applying the HRMPs individually, and when they appear in a HRM system.

Concerning the signs of the parameters for each variable, we expect all sign to be positive, except for the *SECT* variable. In this case, the interpretation has to be made relative to the other sector categories. For what concerns *SIZE*, we expect larger firms to be more likely to innovate, while we expect the likelihood of innovation at the level of the sector to correspond to what is normally thought of as a high-tech/low-tech typology.

B. The Data

The main source of data for this paper is the *DISKO database*. The database is based on a questionnaire which aims at tracing the relationship between technical and organisational innovation in a way that permits an analysis of new principles for work organisation and their implications for the use and development of the employee's qualifications in firms in the Danish private business sector. The survey was carried out by

[9] The way in which the HRM practices are transformed into "systems" will be explained in the section below.

the DISKO project at Aalborg University in 1996. The questionnaire was submitted to a national sample of 4,000 firms selected among manufacturing firms with at least 20 full-time employees and non-manufacturing firms with at least 10 full-time employees.[10] Furthermore, all Danish firms with at least 100 employees were included in the sample, i.e. a total of 913 firms. The resulting numbers of respondents were 684 manufacturing and 1,216 non-manufacturing firms, corresponding to response rates of, respectively, 52 per cent and 45 per cent.[11] The first descriptive analysis of the survey can be found in Gjerding (1997). The database is held by Statistics Denmark, and the data on the firms in the database, can be linked to regular register data, also held by Statistics Denmark. In our case we have obtained data on the size of the firms in the sample from regular register data.

[Table 1, just about here]

Table 1 displays descriptive statistics for our explanatory variables.[12] It can be seen from the Table 1 that between 36 and 84 per cent of the firms in our sample apply each one of the nine HRMPs, described above. 36 per cent apply planned job rotation, while 84 per cent apply delegation of responsibility. 80 per cent of the firms apply at least two of the HRMPs, while 65 per cent apply at least three such practices. For what concerns the distribution on sectors and across size categories, it can be seen that none of the groups are either extremely large nor are there any extremely small groups. Since the analysis contains many different variables, each reflecting different aspects of HRMPs, we have chosen to use principal components analysis in order to reduce the amount of variables in the regression analysis to be carried out subsequently. The principal components technique, a form of factor analysis, estimates linear combinations of the underlying variables, in this case the indices of various work practices, that "explain" the highest possible fraction of the remaining variance in the data set. Thus, the first principal component is estimated to explain the highest possible fraction of the total variance, the second principal component the highest possible fraction of the variance not explained by the first principal component, etc. By maximising the "explained residual variance" in each round, the first m ($< n$) principal components will explain a relatively large proportion of the total variance. It should be pointed out that it is normal to transform (or "smooth") variables using the method of alternating least squares, before conducting a principal components analysis, when variables are discrete. Nevertheless, since our variables are binary such a transformation is not meaningful.

An economic interpretation of the factor loadings is that the "typical" pattern is one in which some of the above mentioned work practices play a major role. Accordingly, we interpret each of the sets of factor loadings as "HRM systems". The sets of factor loading are reported in Table 2. It can be seen from Table 2 that we include five principal components in the analysis. The reason for including five components is that we will

[10] In the stratification of the sample, firms with less than 10 employees were excluded from the analysis. However in our analysis, we have a size category containing firms smaller than 10 employees. The reason for this is that when the sample was stratified, size was measured at a given point in time. However, in this paper we measure size as the number of full time employees over a full year.

[11] The full questionnaire is available in English, as an appendix to Lund and Gjerding (1996, Appendix 1).

[12] Of the total of 1900 responding firms, data are not available for size or for sectoral affiliation for 16 of those firms. Hence, we conduct our analysis using information on 1884 firms.

perform a principal components regression using the principal components from Table 2 in the section below. In this regression it turns out that *FL1* and *FL5* have a positive effect on innovation performance, while neither of the other principal components are associated with higher innovation performance. It can be noted that these five components explain 72 per cent of the total variance. Hence, we only miss out 28 per cent of the total variance by applying the principal components technique.

An example of a HRM system is *FL1* from Table 2. In this case the factor loadings are all positive and have all approximately the same size (factor loadings of about 0.3-0.4), except for firm external training, which is about half the size of the other factor loadings. Nevertheless, *FL1* expresses a HRM system in which eight of our nine HRMPs are equally important. Note that each individual firm which scores high on *FL1* is not necessarily applying all HRMPs simultaneously. However, it does imply that a firm, which scores highly on *FL1* applies several of the HRMPs. Hence this system (*FL1*) is one in which all practices are applied in just about equal proportions. In the same manner *FL2* is dominated by firm-external training (factor loading of 0.85), but to some extent by delegation of responsibility (factor loading of 0.34).[13] Another example of a specific system or configuration is *FL5* which dominated by performance related pay, but also to some extent by firm-internal training.

[Table 2, just about here]

C. Estimation

Since our dependent variable is a discrete variable we apply an ordered probit model as the means of estimation. Hence, the method is maximum likelihood estimation (MLE), which provides a means of choosing an asymptotically efficient estimator for a set of parameters (for an exposition of the properties of ML estimators, see Greene, 1997, p. 129). Although MLE has been criticised for having less than optimal small sample properties (may be biased, since the MLE of the variance in sampling from a normal distribution is biased downwards), we do not consider this to be a major problem, given the fact that our sample contains about 1,900 firms.

The estimations of our model can be found in Table 3. It can be seen from the table that large firms are more likely to innovate than small firms (e.g. in model i), although the effect is not particularly strong. Given that our dependent variable is not a measure of the frequency of innovation this finding is not surprising, but should be controlled for.

[Table 3, just about here]

It can be seen from Table 3 that the likelihood of firms being innovators, given their sectoral affiliation, can be ranked as follows: (1) specialised suppliers, (2) ICT (Information and Communication Technology) intensive services, (3) science based, (4) wholesale trade, (5) scale intensive, (6) supplier dominated, (7) scale intensive services, (8) specialised

[13] Admittedly, it is a weakness of the principal components methodology that the size of each factor loading chosen, for one to conclude that an underlying variable is "important", is somewhat arbitrary.

services, and (9) crafts. Such a ranking must be said to correspond with intuition, related to what is high-tech or low-tech.

The results also confirm that firm's external linkages are important to innovation, since both the parameters for vertical linkages (*LINK*) and for other knowledge linkages (*EXREL*) are significantly different from zero. It can be noted, however, that upstream or upstream linkages are particularly important, given the high parameter for this variable. The latter finding is in line with the predictions of Lundvall (1988) and von Hippel (1988) and with the empirical findings of Rothwell *et al.* (1974) and Malerba (1992). The variable for being a subsidiary has a positive sign, but is not significant.

Using the principal components tool, described above, we identify two HRM systems which are conducive to innovation.[14] The first is *FL1* from Table 2, in which all of our nine HRM variables (interdisciplinary workgroups, quality circles, systems for collection of employee proposals, planned job rotation, delegation of responsibility, integration of functions, performance related pay, firm-internal training, and finally, whether or not the firm in questions uses firm-external training) matter (almost) equally for firm's ability to innovate. The second system, which is found to be conducive to innovation (*FL5* from Table 2) is dominated by performance related pay and to some extent by firm-internal training. It can be noted that we ran a regression using all nine principal components, but none of the factor loadings *FL6-FL9*, turned out to be significant.[15] Nevertheless, based on the principal components regression we can — as a first step — conclude that HRMPs matter for the ability of firms to innovate.

Concerning our HRMP complementarity hypothesis, it can be seen from Table 3 (model ii) that only performance related pay (*HRMP7*) and firm-internal training (*HRMP8*) are individually significant of the total of nine human resource management practices. However, when all HRMPs are combined into a single variable (a "system"), this "synthetic" variable (*FL1*) is highly significant. We take this as evidence of the existence of Edgeworth complementarities between the HRMPs in our analysis. However, while all HRMPs (except for firm-external training) are complementary with respect to innovation performance for one group of firms, for another group of firms, complementarity between firm-internal training and performance related pay appear to the important factor for firms' ability to innovate.

Another way of gauging HRMP complementarities is to look at whether it is sufficient to apply at least two (or one) HRMPs, rather than it being necessary to apply several practices together. In Table 3, model iii, we test the hypothesis of whether having at least two HRMP, against the alternative hypothesis of applying three or more HRMPs at the same time. Although having at least two practice is individually significant (not shown for reasons of space) it is not significant, when taken together with a variable expressing

[14] Other examples of principal components regression include Arvanitis and Hollenstein (1996), in which the effects on innovation performance of various sources of innovation are examined. In the field of international economics, Dalum, Laursen and Verspagen (1999) analysed the effect of international patterns of specialisation on economic growth, while applying the methodology.

[15] We have also experimented with various rotations of the factors, including an orthogonal varimax rotation. By following this procedure, we find that our two successful HRM systems are split into more factors. *FL1* is still significant, but now the important underlying variables consist only of Interdisciplinary workgroups; Quality circles; Systems for collection of employee proposals; and Planned job rotation. Delegation of responsibility; and Integration of functions makes up a separate (successful with respect to innovation) system in this set-up, while Firm-internal training and Performance related pay dominate a (successful) factor each.

whether or not each firm apply three or more HRM practices (*HRMPTHREE*). In contrast *HRMPTHREE* has a positive sign and is highly significant. We take this as further evidence of the importance of Edgeworth complementarities between new HRM practices with respect to determining innovation performance. It can be noted that we have tested our models not only by using an ordered probit model, as documented in the Table 3, but also by making standard binary probit estimations (collapsing our discrete dependent variable into a binary variable, which takes the value of zero if the firm does not innovate and takes the value of one if the firm innovates). This change of estimation method does not change our results in any important way.

The final part of our analysis is devoted to the assessment of whether sectoral regularities in the application of the two (successful) HRM systems can be detected. Despite the fact that the correlation coefficients are not very high in Table 4, we find that of our total of nine sectors, the four manufacturing sectors correlate with the first system, while also firms located in ICT intensive service sectors are associated with the first system, although it should be noted that the correlation coefficient is rather low for this particular sector. Firms belonging to the wholesale trade sector tend to be associated with the second system. Hence it seems fair to conclude in general, that sectoral regularities in the effect of HRMP complementarities on innovation performance, can be detected.

[Table 4, just about here]

IV. Conclusion and Discussion

We began by observing a number of stylised facts pertaining to the ongoing changes in the nature of the employment relation — often conceptualised in the term, "new HRM practices —, to the apparently systemic nature of these practices, and to their adoption by innovative firms. Building on earlier fundamental work, we argued that the notion of complementarities (and the associated theorising and formalisms) was helpful for allowing us to construct explanations of these stylised facts. In particular, we argued that while the adoption of individual HRM practices may be expected to positively influence innovation performance, an adoption of a package of complementary HRM practices could be expected to impact on innovation performance to a much higher degree.

In our empirical analysis of these overall ideas, we began by finding that strong linkages to users or suppliers is conducive to innovation (while controlling for size and sectoral affiliation). Moreover, strong linkages to knowledge institutions, including technical support institutions, consultancies or with universities, was also found to be conducive to innovation. With respect to the application of new HRM practices we applied principal components analysis in order to compress the information from the survey and in order to identify possible patterns of HRM practices. Using this tool we identified two HRM systems which are conducive to innovation. The first is one in which all of our nine HRM variables matter (almost) equally for the ability to innovate. The second system, which was found to be conducive to innovation is dominated by performance related pay and to some extent by firm-internal training as well. Hence, we conclude that the application of HRM practices do matter for the likelihood of a firm being an innovator. Furthermore, since the two HRM systems were strongly significant in explaining innovation performance, while only two individual practices (out of nine) were found to be significant, we found support for the hypothesis of the importance of Edgeworth complementarities between certain HRM practices within each of the two HRM systems.

The final part of our analysis was devoted to assess whether sectoral regularities in the application of the two (successful) HRM systems could be detected. Of our total of nine sectors we found that the four manufacturing sectors correlate with the first system, while also firms located in ICT intensive service sectors are (however weakly) associated with the first system. Firms belonging to the wholesale trade sector tend to be associated with the second system. Theoretical analysis has focussed almost exclusively on identifying organisational practices and complementarities between such practices, invariant to the type of activity in question (e.g. Milgrom and Roberts, 1995). Hence, in order to inform future theoretical research in the field, further empirical research should be devoted to the more detailed unfolding of sectoral regularities in the effect of HRM practice complementarities on innovation performance.

Appendix 1
The Sectoral Classification Applied in this Paper

Pavitt (1984), identifies differences in the importance of different sources of innovation according to which broad sector the individual firm belongs. The taxonomy of firms, according to principal activity, emerged out of a statistical analysis of more than 2000 post-war innovations in Britain and was explained by the sources of technology; the nature of users needs; and means of appropriation. Four types of firms were identified accordingly, namely supplier dominated firms, scale-intensive firms, specialised suppliers and science-based firms. *Supplier dominated* firms are typically small. Most technology comes from suppliers of equipment and material. *Scale intensive* firms are found in bulk materials and assembly. Their internal sources of technology are production engineering and R&D departments. External sources of technology include mainly interactive learning with specialised suppliers, but also inputs from science-based firms are of some importance. *Specialised suppliers* are small firms, which are producers of production equipment and control instrumentation. Their main internal sources are primarily design and development. External sources are users (science-based and scale-intensive firms). *Science based firms* are found in the chemical and electronic sectors. Their main internal sources of technology are internal R&D and production engineering. Important external sources of technology include universities, but also specialised suppliers.

Since the Pavitt taxonomy was created mainly with the manufacturing sector in mind (although our *crafts* sector [see below] could be included in the *supplier dominated* sector, if one were to follow the original Pavitt taxonomy), and since we are conducting an analysis of firms in both manufacturing as well as in services, we have added five additional service sectors. *ICT (Information and Communication Technology) intensive services* are firms providing business services and financial services. *Wholesale trade* consists of firms selling bulk materials or machines. *Scale intensive services* consists of typically large firms in the transport industries, cleaning service as well as of supermarkets and warehouses. *Specialised services* is made up of smaller firms including miscellaneous shops, hotels and restaurants, taxi companies etc. *Crafts* consists of firms in construction industries, as well as of automobile repair shops.

For a detailed assignment of all industries into our nine sectors, see Appendix 2 to this paper.

Appendix 2:
The Assignment of Industries Into Nine Sectoral Categories

No.	Industry	Sector	No.	Industry	Sector
1	Production etc. of meat and meat products	SCAI	43	Sale of motor vehicles, motorcycles etc.	SSER
2	Manufacture of dairy products	SCAI	44	Maintenance and repair of motor vehicles	CRAF
3	Manufacture of other food products	SCAI	45	Service stations	SSER
4	Manufacture of beverages	SCAI	46	Ws. of agricul. raw materials, live animals	WTRA
5	Manufacture of tobacco products	SCAI	47	Ws. of food, beverages and tobacco	WTRA
6	Manufacture of textiles and textile products	SDOM	48	Ws. of household goods	WTRA
7	Mfr. of wearing apparel; dressing etc. of fur	SDOM	49	Ws. of wood and construction materials	WTRA
8	Mfr. of leather and leather products	SDOM	50	Ws. of other raw mat. and semimanufactures	WTRA
9	Mfr. of wood and wood products	SDOM	51	Ws. of machinery, equipment and supplies	WTRA
10	Mfr. of pulp, paper and paper products	SDOM	52	Commission trade and other wholesale trade	WTRA
11	Publishing of newspapers	SDOM	53	Re. sale of food in non-specialised stores	SCIS
12	Publishing activities, excl. newspapers	SDOM	54	Re. sale of food in specialised stores	SSER
13	Printing activities etc.	SDOM	55	Department stores	SCIS
14	Mfr. of refined petroleum products etc.	SCAI	56	Retail sale of phar. goods, cosmetic art. etc.	SSER
15	Mfr. of chemical raw materials	SCIB	57	Re. sale of clothing, footwear etc.	SSER
16	Mfr. of paints, soap, cosmetics, etc.	SCAI	58	Re. sale of furniture, household appliances	SSER
17	Mfr. of pharmaceuticals etc.	SCIB	59	Re. sale in other specialised stores	SSER
18	Mfr. of plastics and synthetic rubber	SCAI	60	Repair of personal and household goods	SSER
19	Mfr. of glass and ceramic goods etc.	SDOM	61	Hotels etc.	SSER
20	Mfr. of cement, bricks, concrete ind. etc.	SCAI	62	Restaurants etc.	SSER
21	Mfr. of basic metals	SCAI	63	Transport via railways and buses	SCIS
22	Mfr. construction materials of metal etc.	SCAI	64	Taxi operation and coach services	SSER
23	Mfr. of hand tools, metal packaging etc.	SDOM	65	Freight transport by road and via pipelines	SSER
24	Mfr. of marine engines, compressors etc.	SPEC	66	Water transport	SCIS
25	Mfr. of other general purpose machinery	SPEC	67	Air transport	SCIS
26	Mfr. of agricultural and forestry machinery	SPEC	68	Cargo handling, harbours etc.; travel agencies	SCIS
27	Mfr. of machinery for industries etc.	SPEC	69	Monetary intermediation	ITIS
28	Mfr. of domestic appliances n.e.c.	SCAI	70	Other financial intermediation	ITIS
29	Mfr. of office machinery and computers	SCIB	71	Insurance and pension funding	ITIS
30	Mfr. of radio and communication equipment etc.	SCIB	72	Activities auxiliary to financial intermediates	ITIS
31	Mfr. of medical and optical instruments etc.	SPEC	73	Letting of own property	SSER
32	Building and repairing of ships and boats	SCAI	74	Real estate agents etc.	SSER
33	Mfr. of transport equipment excl. ships, etc.	SCAI	75	Renting of machinery and equipment etc.	SSER
34	Mfr. of furniture	SDOM	76	Computer and related activity	ITIS
35	Mfr. of toys, gold and silver articles etc.	SDOM	77	Research and development	ITIS
36	General contractors	CRAF	78	Legal activities	ITIS
37	Bricklaying	CRAF	79	Accounting, book-keeping and auditing activities	ITIS
38	Install. of electrical wiring and fittings	CRAF	80	Consulting engineers, architects etc.	ITIS
39	Plumbing	CRAF	81	Advertising	ITIS
40	Joinery installation	CRAF	82	Building-cleaning activities	SCIS
41	Painting and glazing	CRAF	83	Other business services	ITIS
42	Other construction works	CRAF			

SCAI = Scale intensive firms; SDOM = Supplier dominated firms; SCIB = Science based firms; SPEC = Specialised suppliers; CRAF = Crafts; WTRA = Whole sale trade; SSER = Specialised services; SCIS = Scale intensive services; ITIS = ICT intensive services.

References

Acs, Z.J. and D.D. Audretsch (1988) Innovation in Large and Small Firms: An Empirical Analysis. American Economic Review 78: 678-690

Aoki, M. and R. Dore (1994) The Japanese Firm: The Sources of Competitive Strength. Oxford University Press, Oxford

Arvanitis, S. and H. Hollenstein (1996) Industrial Innovation in Switzerland: a model-based Analysis with Survey Data. In: A. Kleinknecht (ed.) Determinants of Innovation: The Message from New Indicators. Macmillan Press Ltd, London

Barney, J.B. (1991) Firm Resources and Sustained Competitive Advantage . Journal of Management 17: 99-120

Barney, J.B. (1995) Looking Inside for Competitive Advantage. Academy of Management Executive 9 : 49-61

Baron, J.N. and D.M. Kreps (1999) Strategic Human Resources: Frameworks for General Managers. John Wiley, New York

Bowman, E.H. and H. Singh (1993) Corporate Restructuring: Reconfiguring the Firm. Strategic Management Journal 14: 5-14

Brouwer, E. and A. Kleinknecht (1996) Determinants of Innovation: A Microeconometric Analysis of Three Alternative Innovation Output Indicators. In: A. Kleinknecht (ed.) Determinants of Innovation: The Message from New Indicators. Macmillan Press Ltd, London

Burns, T. and G.M. Stalker (1961) The Management of Innovation. Tavistock, London

Cohen, W.M. and S. Klepper (1996) A Reprise of Size and R&D. Economic Journal 106: 925-951

Dalum, B., K. Laursen and B. Verspagen (1999) Does Specialization Matter for Growth? Industrial and Corporate Change 8: 267-288

Dosi, G. and L. Marengo (1994) Some Elements of an Evolutionary Theory of Organizational Competences. In: R.W. Englander (ed.) Evolutionary Concepts in Contemporary Economics. University of Michigan Press., Ann Arbor

Freeman, C. (1988) Japan: a New National System of Innovation? In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L.L.G. Soete (eds.) Technical Change and Economic Theory. Pinter Publishers, London

Geroski, P.A. (1990) Innovation, Technological Opportunity, and Market Structure. Oxford Economic Papers 42: 586-602

Gjerding, A.N. (ed.) (1997) Den fleksible virksomhed: Omstillingspres og fornyelse i dansk erhvervsliv. Erhvervsudviklingsrådet, Copenhagen

Granstrand, O., P. Patel and K.L.R. Pavitt (1997) Multi-Technology Corporations: Why They Have 'Distributed' Rather than 'Distinctive Core' Competencies. California Management Review 39: 8-25

Greene, W.H. (1997) Econometric Analysis. Prentice-Hall, Upper Saddle River, New Jersey

Guest, D.E. (1997) Human Resource Management and Performance: a Review and Research Agenda. The International Journal of Human Resource Management 8: 263-276

Harris, R.I.D. and M. Trainor (1995) Innovations and R&D in Northern Ireland Manufacturing: A Schumpeterian Approach. Regional-Studies 29: 593-604

Hayek, F.A.v. (1948) The Use of Knowledge in Society. In: Individualism and Economic Order. University of Chicago Press, Chicago

Henderson, R. (1994) The Evolution of Integrative Capabilities: Innovation in Cardiovascular Drug Discovery. Industrial and Corporate Change 3: 607-630

Holmström, B. and P. Milgrom (1994) The firm as an incentive system . American Economic Review 84 : 972-991

Holmström, B. and J. Roberts (1998) The Boundaries of the Firm Revisited. Journal of Economic Perspectives 12: 73-94

Howells, J. (1984) The Localisation of Research and Development: Some Observations and Evidence from Britain. Regional Studies 18: 13-29

Huselid, M.A. (1995) The Impact of Human Resource Management Practices on Turnover, Productivity, and Corporate Financial Performance. 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. American Economic Review 87: 291-313

Jensen, M.C. and W.H. Meckling (1992) Specific and General Knowledge and Organizational Structure. In: L. Werin and H. Wijkander (eds.) Contract Economics. Blackwell, Oxford

Kleinknecht, A. (ed.) (1996) Determinants of Innovation: The Message from New Indicators. Macmillan Press Ltd, London

Kogut, B. and U. Zander (1992) Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. Organization Science 3: 383-397

Laamanen, T. and E. Autio (2000) Dynamic Complementarities and Technology Acquisition. In: N.J. Foss and P.L. Robertson (eds.) Resources, Technology, and Strategy. Routledge, London

Lado, A. and M.C. Wilson (1994) Human Ressource Systems and Sustained Competitive Advantage: A Competency-Based Perspective. Academy of Management Review 19: 699-727

Lorentz, E. (1998) Organisational Innovation, Governance Structure and Innovative Capacity in British and French Industry. Mimeo. University of Compiégne, Compiégne

Love, J.H., B. Ashcroft and S. Dunlop (1996) Corporate Structure, Ownership and the Likelihood of Innovation. Applied Economics 28: 737-746

Lund, R. and A.N. Gjerding (1996) The flexible company innovation, work organisation and human resource management. DRUID Working Paper no. 17. IKE Group/DRUID, Department of Business Studies, Aalborg

Lundvall, B.-Å. (1988) Innovation as an Interactive Process - from user-producer Interaction to National Systems of Innovation. In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L.L.G. Soete (eds.) Technical Change and Economic Theory. Pinter Publishers, London

Malerba, F. (1992) Learning by Firms and Incremental Technical Change. Economic Journal 102: 845-859

March, J.G. (1991) Exploration and Exploitation in Organizational Learning. Organization Science 2: 71-87

Mendelson, H. and R.R. Pillai (1999) Information Age Organizations, Dynamics, and Performance. Journal of Economic Behavior and Organization 38: 253-281

Michie, J. and M. Sheehan (1999) HRM Practices, R&D Expenditure and Innovative Investment: Evidence from the UK's 1990 Workplace Industrial Relations Survey. Industrial and Corporate Change 8: 211-234

Milgrom, P., Y. Qian and J. Roberts (1991) Complementarities, Momentum, and the

Evolution of Modern Manufacturing. American Economic Review (PaP) 81: 85-89

Milgrom, P. and J. Roberts (1990) The Economics of Modern Manufacturing Technology, Strategy and Organization. American Economic Review 80: 511-528

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

Nelson, R. (1980) Production Sets Technological Knowledge and R and D: Fragile and Overworked Constructs for Analysis of Productivity Growth. American Economic Review 70: 62-67

Pavitt, K.L.R. (1984) Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. Research Policy 13: 343-373

Pavitt, K.L.R. (1998) Technologies, Products and Organization in the Innovating Firm: What Adam Smith Tells us and Joseph Schumpeter Doesn't. Industrial and Corporate Change 7: 433-452

Porter, M.E. (1996) What is Strategy? Harvard Business Review 74: 61-80

Rothwell, R., C. Freeman, P. Jervis, A. Robertson and J. Townsend (1974) SAPPHO Updated -Project SAPPHO Phase 2. Research Policy 3: 258-291

Schumpeter, J.A. (1912/1934) The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle. Oxford University Press, London

Tushman, M.L. and W.L. Moore (eds.) (1988) Readings in the Management of Innovation. Ballinger Publishing Co., Cambridge, Massachusetts

von Hippel, E. (1988) The Sources of Innovation. Oxford University Press, New York and Oxford

Zenger, T. and W.S. Hesterly (1997) The Disaggregation of Corporations: Selective Intervention, High-Powered Incentives and Molecular Units. Organization Science 8: 209-222

Table 1*: Descriptive statistics for a set of DISKO variables (n=1884)*

Variable	Number of firms	% of total sample
Interdisciplinary workgroups	923	49.0
Quality circles	707	37.5
Systems for collection of employee proposals	828	43.9
Planned job rotation	673	35.7
Delegation of responsibility	1585	84.1
Integration of functions	1061	56.3
Performance related pay	734	39.0
Firm-internal training	976	51.8
Firm-external training	1305	69.3
At least two HRMP applied (*HRMPTWO*)	1497	79.5
At least three HRMPs applied (*HRMPTHREE*)	1229	65.2
Scale intensive	254	13.5
Supplier dominated	225	11.9
Science based	67	3.6
Specialised suppliers	138	7.3
Crafts	273	14.5
Wholesale trade	333	17.7
Specialised services	370	19.6
Scale intensive services	94	5.0
ICT intensive services	130	6.9
1-10 employees	221	11.7
11-50 employees	979	52.0
51-100 employees	205	10.9
100+ employees	479	25.4

Table 2: ***Factor loadings for nine organisational variables***

Variable	FL1	FL2	FL3	FL4	FL5
HRMP1: Interdisciplinary workgroups	0.41	-0.07	0.07	-0.25	-0.13
HRMP2: Quality circles	0.38	-0.22	0.29	-0.09	-0.19
HRMP3: Systems for collection of employee proposals	0.36	-0.09	0.30	0.23	-0.23
HRMP4: Planned job rotation	0.34	-0.25	0.27	0.22	-0.07
HRMP5: Delegation of responsibility	0.32	0.34	-0.53	-0.05	-0.24
HRMP6: Integration of functions	0.34	0.01	-0.53	0.10	-0.25
HRMP7: Performance related pay	0.30	-0.18	-0.23	0.49	0.72
HRMP8: Firm-internal training	0.31	0.04	0.03	-0.73	0.48
HRMP9: Firm-external training	0.19	0.85	0.36	0.20	0.13
Cumulative %	0.34	0.45	0.55	0.64	0.72

Table 3*: Probit regression, explaining innovative performance across 1884 Danish firms*

Variable	Model (i) Estimate	Model (i) *p*-value	Model (ii) Estimate	Model (ii) *p*-value	Model (iii) Estimate	Model (iii) *p*-value
Sector controls						
Scale intensive	-0.237	0.075	-0.242	0.068	-0.250	0.054
Supplier dominated	-0.269	0.047	-0.269	0.047	-0.302	0.022
Science based	-0.153	0.395	-0.158	0.379	-0.135	0.445
Specialised suppliers	0.089	0.546	0.098	0.502	0.065	0.648
Crafts	-0.945	0.000	-0.935	0.000	-0.965	0.000
Wholesale trade	-0.212	0.095	-0.214	0.090	-0.208	0.091
Specialised services	-0.698	0.000	-0.693	0.000	-0.726	0.000
Scale intensive services	-0.707	0.000	-0.720	0.000	-0.749	0.000
ICT intensive services	Benchmark		Benchmark		Benchmark	
SIZE	0.014	0.080	0.014	0.084	0.017	0.026
LINK	0.587	0.000	0.586	0.000	0.634	0.000
EXREL	0.253	0.000	0.256	0.000	0.285	0.000
SUBSID	0.087	0.179	0.084	0.193	0.134	0.032
FL1	0.132	0.000				
FL2	0.000	0.990				
FL3	-0.034	0.283				
FL4	-0.038	0.239				
FL5	0.121	0.000				
HRMP1			0.064	0.374		
HRMP2			-0.066	0.342		
HRMP3			0.101	0.127		
HRMP4			0.069	0.308		
HRMP5			0.100	0.296		
HRMP6			0.065	0.327		
HRMP7			0.218	0.001		
HRMP8			0.299	0.000		
HRMP9			0.021	0.758		
HRMPTWO					0.120	0.271
HRMPTHREE					0.323	0.000

Table 4: ***Correlations amongst HRM systems and the firm's sectoral affiliation***

	FL1	*p*-value	FL5	*p*-value
Scale intensive	0.17	0.000	0.02	0.453
Supplier dominated	0.07	0.001	-0.03	0.230
Science based	0.13	0.000	0.00	0.878
Specialised suppliers	0.14	0.000	-0.04	0.088
Crafts	-0.23	0.000	0.01	0.625
Wholesale trade	0.00	0.833	0.07	0.003
Specialised services	-0.17	0.000	-0.03	0.207
Scale intensive services	-0.04	0.064	0.02	0.485
ICT intensive services	0.05	0.031	-0.04	0.106