

The importance of human resources in the development and innovation

prof. dr. Miroslav Lutovac , Abdulkarem Emhmed Shtawa

Abstract—Human resource management (HRM) practices are generally expected to stimulate a firm's innovation performance. However, which of these practices do really pay off? Based on a unique dataset that includes detailed information for both a firm's innovation activities and different types of HRM practices we find that primarily new workplace organization practices seem to enhance a firm's innovation activities. Flexible practices of working time management and incentive payment schemes show only small effects on both innovation propensity and innovation success. Further training does only affect innovation success, but not innovation propensity. Overall, we find a stronger linkage between innovative HRM practices and innovation propensity than with innovation success.

Keywords: human resource management; workplace organization; innovation performance

1 INTRODUCTION

Starting point of this study is the general idea that the internal of a firm plays an important role for high economic performance. Older economic literature has mostly focused on various types of incentive pay contracts as a main organizational arrangement for achieving greater effort from employees (see for a review in Murphy 1999). Incentive payment is always relevant; but in addition, managers introduce all kinds of human resource management (HRM) practices that complement (or even substitute) pure incentive pay plans. As Briody (2012) puts it in Fiscal Times: "Companies like IBM, Best Buy, Netflix and HubSpot, for example, have stopped counting employees' vacation days. Philip Rosedale, the founder of Second Life maker Linden Lab, recently had his employees vote on how to divvy up the quarterly bonuses. Google, for its part, is well known for having official 'hang out' spaces in the office, and allowing employees to spend 20% of their time on a side project of their choosing. Another CEO, Joe Reynolds of Red Frog Events in Chicago, Ill., even installed a tree house with a zip line in the middle of his office." How could such organizational arrangements pay off? The motivation that is often proclaimed by those who favor such arrangements is that new HRM practices could encourage employees to think independently, creatively and to feel more motivated in their work. Accordingly, the expectation is that HRM should directly stimulate innovation and economic performance of a firm. Newer theoretical research takes into consideration new human resource management (HRM)

practices explicitly such as employee training , teamwork , job design and internal hierarchies that aim at enhancing employee performance (see reviews in Gibbons 1998; Ichniowski and Shaw 2003; and Bloom and Van Reenen 2010).

In this paper , we focus on the relative impact of a broad spectrum of factors of workplace organization and employment conditions on the propensity to innovate and on innovation success (as represented by the sales of innovative products), which is a rather under-researched topic as compared to existing empirical research on the influence of such practices on firm productivity. The idea is that not all HRM practices have the same impact on innovation performance. The considered factors can be grouped into four categories. Factors that are related to (a) workplace organization (e.g., number of hierarchical levels, degree of decentralization), (b) working time management (e.g., flexibility of the work schedule, extent of part-time employment), (c) incentive pay (e.g., individual performance pay schemes, group performance pay schemes) and (d) training intensity. As already mentioned, the relationship between innovation activities and HRM practices has been rarely analyzed so far. This is primarily due to limited data availability as it is hardly possible to find data that includes information on innovation activities and HRM practices at the same time (see Michie and Sheehan 1999). Accordingly, previous studies were mostly based on small samples comprising only one cross-section. Our dataset comes

from a survey that includes both detailed information on the firms' innovation activities and their HRM practices. The survey is based on a representative sample of Libyan firms and was conducted in 2005, 2008 and 2012, respectively. The detailed information on different HRM practices allows us to analyze the relative impact of different HRM practices and the identification of cumulative effects when different practices are used simultaneously. A further asset of our study is the detailed information on a firm's innovation activities. While previous studies exclusively investigated simple indicators of innovation propensity, we also analyze the impact of HRM practices on a measure of innovation success. We find that variables representing workplace organization show overall highly significantly positive associations with innovation propensity. Some of them seem to be more important than other "standard" determinants of innovation such as demand development, competition conditions or human capital endowment. New workplace organization practices are also important drivers for innovation success, their effect on innovation success is, however, limited. A further finding is that the intensity of further training is positively associated with innovation success, but not with innovation propensity. Working time management practices and incentive payment schemes appear to have only a small impact on both innovation propensity and innovation success. Overall, we find much stronger linkages between innovative HRM practices and innovation propensity than with innovation success.

The paper is structured as follows: Section 2 provides the conceptual background, results from previous empirical studies and our research hypotheses. Section 3 describes the data we use in our estimations. Section 4 discusses our econometric approach and the variables we use in our estimations. Section 5 presents the estimations results. In Section 6, we summarize our results and draw conclusions.

2 CONCEPTUAL BACKGROUND, RELATED EMPIRICAL LITERATURE AND RESEARCH HYPOTHESES

2.1 CONCEPTUAL BACKGROUND

The main rationale for firms applying HRM systems is that a firm needs a system for assigning decision rights to individuals who have the knowledge and abilities relevant to such decisions (Jensen and Meckling 2005). The impact of HRM practices, particularly the impact of workplace organization on productivity has been widely studied in both management and economic literature.

Economic literature has widened its focus from focusing on incentive pays to including various HRM practices concerning employee training, hiring criteria, teamwork, job design and employee hierarchies (see Ichniowski & Shaw 2003). In management literature, a major concern is the proper alignment of competitive strategy with HRM practices and potential complementarity of these practices. The main focus is on the impact of HRM practices bundled in HRM systems on firm performance measures (Huselid 1995).

The economic literature distinguishes between "innovative" and "traditional" HRM practices. However, there is no consensus for an all-encompassing list of practices that can be assigned to one or the other group. For example, Ichniowski and Shaw (2003, p. 157) list several HRM practices that can be considered "innovative": "Problem solving teams are aimed at involving production workers or other non-managerial workers in solving production problems. Rotation of workers across jobs is used to increase worker flexibility and increase teamwork. Careful screening and selection of workers is required to identify those who have both high-level job- and task-related skills and also "team skills" to work together to solve problems. Job security is used to assure workers that improvements in production performance will not result in the direct loss of jobs. Information sharing is important to provide the information and motivation for greater involvement and decision making. Training is needed to do problem solving, to increase knowledge for better decision making and to introduce workers to the skills needed for more job tasks. Finally, incentive pay, in a wide variety of forms, is introduced to provide the incentive for greater employee effort and employee involvement in decision making." Generally, with innovative HRM practices, workers make decisions both individually and collectively necessitating greater exchange of information within teams (Mookherjee 2006). In contrast, more traditional HRM practices typically include hourly or salaried pay with little connection of pay to performance outcomes, assignment of workers to narrowly defined jobs with no job rotation, no work teams, hiring practices with limited screening for non-managerial or professional jobs, little formal training, limited sharing of operating data with employees and layoffs of employees when product demand declines.

Innovative HRM is expected to have a larger impact on a firm's performance. According to Mookherjee (2006), a theory explaining the superiority of innovative HRM practices would need to incorporate costs of communication, information processing and contract renegotiation as these factors would make the difference between innovative HRM and traditional HRM practices (in the absence of such costs, the value of centralized decision-making should be higher). However, delegated decision making is associated with other costs of control loss and a lack of coordination, which have to be traded off against enhanced flexibility. Further advantages of innovative HRM practices such as decentralization and information sharing are increased firms' speed of response to market changes and higher job satisfaction (Bloom et al. 2010).

Whereas most concepts focus on the impact of HRM practices on productivity, the question whether innovative HRM practices also stimulate innovative activity and innovative performance has gained much less attention. The question deserves our interest as innovation is very often a team activity and incentive systems for innovations work different than in other economic contexts.

(Holmström 1989; Azoulay and Lerner 2013). Teamwork might enhance a more efficient use of Knowledge and lead to recombination of separated knowledge. In addition, decentralization allows for the discov-

ery and utilization of knowledge and job rotation might increase knowledge diffusion (Laursen and Foss 2003). Finally and according to Zoghi et al. (2010), firms might offset some of the coordination costs of decentralization and information-sharing by using incentive pay.

In sum, there is a bundle of explanations for a positive effect of innovative HRM practices on firm performance (and innovation), but – as stated by Mookherjee (2006) – there is a lack of theoretical models (especially formal models) going beyond descriptive formulations and speculations, and – as we will see in the next section – limited exchange between theoretical and empirical literature.

2.2 Related empirical literature

Most studies found empirical support for the hypothesis that investments in HRM practices are associated with greater productivity (e.g., Huselid 1995; Ichniowski 1997; Black and Lynch 2001; for a review see Bloom and Van Reenen 2010). The results of Huselid (1995) indicated that high performance work practices have a significant impact on turnover and productivity as well as short- and long-term measures of corporate financial performance. Black and Lynch (2001) found that it is more important for the impact on productivity how a work practice is implemented rather than whether a work practice is implemented. Boning et al. (2001) showed that group-based incentive pay raises productivity and that the adoption of teams in addition to incentive pay leads to a further increase in productivity (especially in complex production lines). In a seminal paper, Bresnahan et al. (2002) showed that the effects of information technology (IT) on labor demand are greater when IT is combined with workplace reorganization. Bloom and Van Reenen (2007; 2010) found that survey-based measures of monitoring, target-setting and incentives are strongly associated with firm-level productivity and other measures of firm performance. The question whether there is an impact of HRM practices on innovation has received less attention. Michie and Sheehan (1999) showed that innovative work practices are positively correlated with investment in R&D and new technology as compared to traditional work practices. Laursen and Foss (2003) investigated the relationship between systems of HRM and the probability of introducing innovations for a sample of Danish firms. The HRM systems that are identified and used in the econometric analysis are combinations of HRM practices that emerge out of a principal component factor analysis and are strongly significant in explaining innovation performance, whereas only two individual practices were found to be strongly significant (“integration of functions” and “firm-internal training”). They interpret this result as evidence that supports their hypothesis of complementarities between HRM practices. In another study also based on data for Danish firms, Foss and Laursen (2005) examined the relationship between work practices and innovation the other way round, namely the association of a firm’s ability to produce innovations with increasing degree of novelty with the likelihood of adopting delegation of responsibility and pay-for-performance schemes.

Vinding (2006) showed for another sample of Danish firms that the application of HRM practices is positively correlated with the ability to innovate. Shipton et al. (2005, 2006) found that training, induction, team working, appraisal and focus on exploratory learning are predictors of innovation and that innovation is enhanced if there is a supportive learning climate. Acemoglu et al. (2007) examined the relationship between diffusion of innovations and the decentralization of British and French manufacturing firms. They showed that firms closer to the technological frontier, firms in more heterogeneous environments and younger firms are more likely to choose decentralization. Hempell and Zwick (2008) investigated the effects of two organizational practices, employee participation and outsourcing, on the likelihood of the introduction of products and/or process innovations. The results, based on data for 900 German firms in the years 2002 and 2004, showed that employee participation is positively associated with product and process innovations, while outsourcing favors innovations in the short run, but reduces innovation performance in the long run. Zoghi et al. (2010) analyzed the relationship between decentralization, information-sharing, incentive pay schemes and innovation for a large sample of Canadian firms and three cross-sections. Although they found correlations between these factors, they show that the correlation is weaker for decentralized decision-making or incentive pay programs compared to the correlation between information-sharing and innovation. Exploiting the panel structure gives no clear evidence on the proposed relationships. Using four waves of a survey of firms from the Netherlands, Zhou et al. (2011) found that high functional flexibility is positively associated with sales of new products. In contrast, they did not find any impact of external labor turnover on innovation since innovation leaders who need to continuously accumulate tacit knowledge favored longer commitments of workers to their firms.

For a sample of UK firms, Cosh et al. (2012) found that decentralized decision-making generally supports the ability to innovate in small and medium-sized enterprises and that young firms in high technology sectors with informal structures have a greater tendency to be innovative, whereas firms in other sectors are better suited with formal structures. In a study with Taiwanese firms, Chang et al. (2012) show that there is a positive relationship between organizational capabilities and radical innovation. Jiang et al. (2012) show for Chinese firms that hiring and selection, reward, job design, and teamwork are positively related to employee creativity that influences innovation, whereas training and performance appraisal are not. Using data on Finnish manufacturing firms, large firms (in contrast to small firms) with more decentralized decision-making are not found to perform better in terms of innovation than those with a more bureaucratic decision-making structure (Koski et al. 2012). Performance-based wages are found to relate positively to innovation if they are combined with a systematic monitoring of the firm’s performance. Arvanitis et al. (2013) investigated the relationship between indicators for the intensity of use of ICT, several forms of workplace

organization, and human capital and innovation performance for Swiss and Greek firms. The organizational variables for new work design (teamwork, job rotation, reduction of managerial levels) and employee voice (decentralization and delegation) have been found to show significant positive marginal effects for all innovation indicators in the Swiss sample. In sum, all studies find a stable positive relationship between decentralization of decision-making, delegation of responsibility, information-sharing and innovation and when examined – a positive relationship of teamwork and training with innovation. These basic relationships seem to hold irrespective of the cultural background of the surveys, the sample size, the definition of the variables of interest, and other measurement issues. A general limitation of all these studies, however, is that they analyze the impact of certain HRM practices and do not control for others.

Accordingly, it is hardly possible to make a statement about the relative impact of a certain practice and their complementarities with each other. In contrast, our study is based on a unique dataset that allows to control simultaneously for different aspects of innovative HRM practices and thus to discuss their relative importance.

2.3 RESEARCH HYPOTHESES

Based on existing studies, we investigate the relationship of a broad spectrum of factors of workplace organization and employment conditions (HRM practices) on the propensity to innovate and innovation success as represented by the sales of innovative products.¹ The practices taken into consideration can be grouped into four categories. Practices that are related to (a) workplace organization (e.g., number of hierarchical levels, extent of decentralization), (b) working time management (e.g., flexibility of the work schedule, extent of part-time employment), (c) incentive pay (e.g., individual performance salary, group performance salary) and (d) training intensity.

Based on the literature discussed above we expect the following effects:

HYPOTHESIS 1: The redesign of workplace organization as reflected in practices such as teamwork and job rotation, the reduction of hierarchical levels and the extent of decentralization of decision-making has a positive association with (a) the propensity to innovate and (b) innovation success.

HYPOTHESIS 2: Flexible practices of working time management have a positive association with (a) the propensity to innovate and (b) innovation success.

HYPOTHESIS 3: Payment schemes that increase incentives through incentive payment have a positive association with (a) the propensity to innovate and (b) innovation success.

HYPOTHESIS 4: The intensity of further training provided to a firm's employees has a positive association with (a) the

propensity to innovate and (b) innovation success.

3 DESCRIPTION OF THE DATA

The firm level data used in this study were collected in the course of three surveys among Libyan companies conducted in 2005, 2008 and 2012, respectively. All surveys were based on a sample which covers manufacturing industry, construction and the telecommunications sector and is (with respect to firm size and two-digit industry affiliation) disproportionately stratified. The three surveys yielded data for 2555, 2172 and 2363 firms, respectively, representing response rates of 38.7%, 33.8% and 35.9%, respectively. The data were pooled to a dataset of a total of 7090 observations. The final sample used for model estimation was significantly smaller (about 4500 observations), primarily due to the fact that the questions on organizational practices were answered only by firms with more than 20 employees. As there is a large time lag between the surveys (three years), only about 50% of the firms replied to two successive surveys, meaning that the panel is highly unbalanced (what, as shown in the next section, is not without consequences for the choice of the econometric method used for model estimation).

The three questionnaires, contain questions about the firms' innovation activities, the adoption of several ICT technologies (internet, intranet, extranet, etc.) and the intra-firm diffusion of some of these elements, the use of new organizational practices (team - work, job rotation, employees' involvement in decision-making, etc.) and the employees' educational level. The three surveys also collected information on some financial variables and basic structural characteristics of firms

4 ECONOMETRIC FRAMEWORK

4.1 MODEL SPECIFICATION

As mentioned in the introductory section, our dependent variables are (a) a firm's innovation propensity (indicating whether a firm has introduced innovations in a certain period or not) and (b) innovation success as measured by firm's innovative sales of innovative (new and considerably modified existing) products. As theory does not offer specific explanations for innovation propensity and innovation intensity, we use the same set of independent variables in the two empirical models. To capture different effects on innovation activities, we include the variables describing the HRM practices in an extensive basic model (for a detailed definition of the variables and respective descriptive statistics see Table 1, Table A.1 and Table A.2 in the appendix, respectively).

1. However, we do not cover organizational changes such as vertical integration, mergers, outsourcing, and offshoring within multinational firms (see Bloom et al. 2010 on this point).

Following the theoretical literature and in accordance with empirical studies (see Cohen 2010 for an excellent review of research on innovation determinants; see also Acemoglu et al.

2007), we control in detail for the firms' human capital endowment, ICT usage, market conditions and general firm characteristics such as firm age and firm size. To capture industry specific effects, we further include industry specific time-fixed effects.

Innovation propensity is proxied by a variable that measures whether a firm has product and/or process innovation or no innovation.² The quantitative dependent variable measuring innovation success (sales of innovative products) is measured only for firms which actually have innovation activities.

4.2 SELECTIVITY BIAS

In case of the binary dependent variable measuring a firm's innovation propensity estimating probit regressions is an adequate procedure. To take into consideration firm heterogeneity we use random - effects models. As already mentioned, the variable for innovation success refers only to firms with innovation activities. Consequently, selectivity bias may be a problem. We estimate a two-stage Heckman selection model to detect a potential bias (see Heckman 1979). We use the same set of explanatory variables in the selection equation (innovation yes/no) as in the intensity equation (sales of innovative products) with the exception of the additional identifying variable "regulated_access_libyan_market" (for definition see Table 1) that is used to make sure that the estimated coefficients are reliable (see Wooldridge 2002). This instrument is a 3-digit industry average³ of a variable that measures whether a firm's innovation activities are hampered by limited access to strongly regulated markets in Libya. In line with Cassiman and Veugelers (2002, p. 1174), we assume that this industry variable picks up the effect of unobserved industry-specific attributes that contribute to the potential endogenous firm-specific variables. Accordingly, it can be assumed that the instrument is uncorrelated with the error term. Furthermore, this variable should be a good instrument as the large amount of the regulation-related costs are expected to be fixed and should thus affect selection (innovation yes/no) but not innovation intensity. The effective relationship can also be observed in the data. The effect of the variable "regulated_access_libyan_market" is statistically significant in the innovation propensity equation but insignificant in the innovation intensity model (see Table A.3 in the appendix). As the inverse mills ratio is statistically insignificant at the 10%-level, there is no evidence for a selection bias (see Table 2). To take firm heterogeneity into consideration we estimate random-effects GLS models for innovation success.

4.3 FURTHER ECONOMETRIC ISSUES: OMITTED VARIABLE BIAS AND CAUSALITY

A further potential problem is the possibility of omitted variable bias that would imply inconsistent estimates. A possible way to reduce this problem – run a fixed effects model – can be ruled out in this case. Firstly, as our panel is highly unbalanced (see Section 3) the number of observations that may be used for estimating fixed-effects models is by much lower than in case of random-effects models. Hence, we would lose the

representativeness of our sample. Secondly, as the variance of our model variable across time is rather low, it would hardly be possible to identify within effects.

However, since a broad set of observables that generally affect innovation is included in the estimation equations besides the HRM variables, we expect that there is no omitted variable bias and that the estimated parameters measure firm-specific effects only.

Causality is another potential problem that we cannot directly deal with. As a consequence, we refrain from making causal claims. Instead, our estimation results are interpreted as partial correlations. Nevertheless, some robust regularities come out, which, if interpreted in view of our hypotheses presented in Section 2.3 and their theoretical and empirical support outlined in Section 2.2, could possibly indicate the direction of causal links.

5 ESTIMATION RESULTS

The results for the basic model are presented in Table 2. Columns (1) and (2) show the random- effects probit estimates for the innovation propensity, columns (3) and (4) the random-effects GLS estimates for the innovation intensity.

The columns with uneven numbers show the estimation results for the variables as defined in Table 2. As we are interested in the relative impact of the different variables, the columns with even numbers show the results for the same estimations based on standardized variables (average 0; standard deviation 1) that allow for the comparison of the relative strength of different independent variables (see Agresti 1996; Menard 2011).

The coefficients of the control variables show the expected positive signs in the innovation propensity equation and are all statistically significant except for firm age. For the sales of innovative products, the coefficient of firm age is negative and statistically significant meaning that younger firms are more successful with their innovations on the market than older ones, which is in line with the finding of previous studies (see, e.g., Huergo and Jaumandreu 2004). The results for the HRM variables are discussed in detail in the next two sub-sections.

² We alternatively estimated our model separately for product and process innovation. However, results differ only marginally between the two types of innovation (see Table A.5 in the appendix).

³ The industries are defined according to the NACE classification. We excluded the value of the observation itself in order to ensure the exogeneity of these variables. If the number of observations of a specific 3-digit industry is lower than five, we used the average score at the NACE two-digit level

5.1 INNOVATION PROPENSITY

We comment on the results for the standardized variables in column (2). The practices that characterize the redesign of

workplace organization show positive associations with innovation propensity. The coefficients of the respective variables are strongly statistically significant except for the variable that measures the decrease of the number of hierarchical levels that has the expected positive sign but is not statistically significant at the 10% test level. Of the three practices referring to working time management only the variable that measures the importance of work schedule flexibility shows a positive but weakly significant association with innovation propensity.

The extent of temporary and part-time employment does not appear to have an effect on innovation. All three incentive payment schemes do not show any significant association with innovation propensity in our estimation. Among the considered HRM practices, variables referring to workplace organization have the largest coefficients of the standardized variables in the innovation propensity equation. The difference between the coefficients of each of the (standardized) workplace organization variables and the (standardized) variable for work schedule flexibility is statistically significant. This means that a change by one standard deviation in the extent of use of teamwork, the share of employees that switched function, the extent of use of job rotation or the extent of decentralization is associated with a significantly larger change of the innovation probability than a change by one standard deviation in the extent of work schedule flexibility. Furthermore, the coefficients of the workplace organization variables have significantly larger magnitudes than all control variables with the exception of firm size. The coefficients of the variables for workplace organization do not differ significantly from each other.

It seems plausible that innovative firms that use human capital and information technologies to a large degree would also apply workplace organization practices that are related to more flexible forms of work and cooperation as well as to stronger employee participation in decision-making more intensively than non-innovators. It also appears sensible that working time flexibility is a further characteristic that is in line with more innovative environments. Obviously, the use of incentive payment schemes does not make the difference between innovative and non-innovative firms at the first place. However, it does make a difference as to innovation success (see below), as production and marketing get interlocked between research and development and the market.

5.2 INNOVATION SUCCESS

The effect of HRM practices on innovation success seems to be more limited. We also comment on the results for the standardized variables in column (4). Of the practices belonging to workplace organization only the share of employees that switched function or department (functional flexibility) and the variable that measures the extent of decentralization of decision-making show statistically significant positive associations with the sales of innovative products. Further, the variable based on firm performance pay shows a significantly positive but weak association with standard deviation in the extent of work schedule flexibility. Furthermore, the coefficients of

the workplace organization variables have significantly larger magnitudes than all control variables with the exception of firm size. The coefficients of the variables for workplace organization do not differ significantly from each other.

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For innovation success, the coefficients of the two statistically significant workplace organization variables for the share of employees that have switched function or department and the extent of decentralization are also not statistically different from each other. The coefficient of further training is slightly smaller in magnitude compared with the workplace organization variables, but the difference is not significant. A comparison of the size of the coefficients of the HRM variables with the control variables indicates that the impact of HRM practices is much smaller with respect to innovation success than with respect to innovation propensity. Firm size has the largest relative importance for innovation success, followed by the share of employees with tertiary-level education and firm age.

With respect to our hypotheses we thus conclude that hypothesis 1 receives empirical support, as there is a positive linkage between workplace organization practices and both innovation propensity and success. However, the relationship between workplace organization practices and innovation propensity seems to be stronger than the linkage between workplace organization practices and innovation success. The ex-

tent of use of teamwork and job rotation is positively correlated only with innovation propensity but not innovation intensity. Hypotheses 2 and 3 are only weakly confirmed. Work schedule flexibility, one out of three variables reflecting a firm's working time management, is slightly positively correlated with innovation propensity. Salary based on firm performance, one out of three variables reflecting a firm's incentive pay schemes, is positively correlated with innovation success. Accordingly, the correlation of working time management and incentive pay schemes with innovation performance seems to be rather weak. Finally, hypothesis 4 is confirmed only with respect to innovation success but not with respect to innovation propensity.

5.3 OVERALL EFFECTS OF THE GROUPS OF HRM PRACTICES

In a further step we conducted a principal component factor analysis of all 12 HRM practices that are taken into consideration in this study in order to get an idea of the overall effect of each of the four categories of HRM practices in which we have already grouped the 12 individual practices. We could identify three groups of HRM practices (see Table 3 for detailed information on the factor pattern matrix) that correspond quite well to the a priori categories we have constructed. Factor 1 contains primarily the three practices related to incentive payment. Factor 2 corresponds to the four components of workplace organization (rather small loadings for job rotation and decrease of the number of hierarchical levels, large loadings for the share of employees that switched function, teamwork and decentralization). Further training also belongs to this factor, which is quite plausible in the light of empirical literature that finds a close positive relationship between human capital and new workplace organizational measures (see, e.g., Arvanitis 2005). Factor 3 covers the three working time management practices.

The factor values of the three-factor solution were inserted as independent variables in the estimation equations for innovation propensity and innovation success. The estimates are found in Table 4. We find positive coefficients for all three factors but only factor 2 (workplace organization) is statistically significant for both innovation variables. Factor 1 (incentive payment schemes) is only statistically significant in the innovation success equation, factor 3 (working time management) only in the propensity equation.

The coefficient of factor 2 is significantly larger than the coefficient of factor 3 (working time management) in the propensity equation as well as the coefficient of factor 1 (incentive payment schemes) in the innovation success equation.

On the whole, these results are quite in accordance with those for the individual practices in Table 2. Moreover, they demonstrate more clearly the relative overall importance of the three categories of HRM practices (training is included in factor 2) with respect to innovation performance: workplace organization has the highest importance, working time management the second-highest, and incentive payment schemes have the lowest importance.

5.4 EFFECTS OF COMBINATIONS OF INDIVIDUAL HRM PRACTICES

Complementarities between and/or cumulative effects of the use of HRM practices is a major concern in economic literature (see Section 2.1). Because the results of existing empirical studies are heterogeneous and the methods not always consistent to each other, it is difficult to make a generalizing statement on how the HRM practices are exactly interconnected and which HRM practices influence other ones that might mediate the relationship with (innovation) performance.

We used a method based on Ichniowski et al. (1995, 1997) to examine which combinations of HRM practices show larger associations with innovation than others. This is not a test on complementarity, but it contributes to a better understanding of the interdependence of such practices.

First, we created a dummy for each HRM practice variable that takes the value 1 when the firm ranks "high" for this practice and 0 when the firm ranks "low". As the variables are scaled quite differently, we use the median of the underlying distributions of the original variables (i.e., not the logarithms of them) as cut-off value ("low" versus "high") except for the variable Δ _hierarchical_levels that is already 0/1 coded.4 These twelve dummy variables are summed into a 0-to-12 HRM index. Based on the frequencies of the individual practices in this index, we defined four HRM systems that roughly involve the same number of firms: HRM index=0-2 practices (HRM system 1), HRM index=3-4 practices (HRM system 2), HRM index=5-6 practices (HRM system 3), HRM index=7-11 practices (HRM system 4). In this way, to each of the 12 single practices is assigned the same weight. There are no firms in our sample that have adopted all twelve practices to a sufficient degree so that all twelve dummies would take the value 1. Only a small number of firms have adopted more than nine practices (1.05%) or - conversely - no practice at all (0.84%). The bulk of firms have adopted three to six HRM practices (66.85%).5 Table 5 shows estimation results after inserting the HRM systems using HRM system 1 as reference group. The coefficients of the HRM systems are all positive and strongly statistically significant in the innovation propensity equation. The general impression is that the coefficients are the larger the more HRM practices are combined within an HRM system. Chi-squared-tests on the equality of coefficients show that the coefficient of HRM system 2 is significantly different from that of HRM systems 3 and 4. Thus, our first finding is that firms that use more than 2 HRM practices show a significantly higher innovation propensity than firms with less than 2 practices. Further, the use of 5 and more of the 12 HRM practices is associated with a larger probability of innovation than the use of less than 5 practices. Both findings can be interpreted as hints for some kind of cumulative effect of the combined use of HRM practices on the propensity of innovation. In the estimates for the sales of innovative products only the coefficient of HRM system 4 is positively statistically significant.

The threshold for the cumulative effect of the combined use of HRM practices is in this case higher (from 7 HRM

practices on).

A complementarity test would imply that the magnitude of the innovation effects of the HRM systems is larger than the sum of the effects from adopting each individual practice. Although we do not explicitly test for complementarities in this way and we thus cannot say anything about the sum of the coefficients of the individual practices as compared to the coefficients of the HRM systems, a simple inspection of the magnitude of the coefficients of the individual practices in Table 2 or Table A.4 and the HRM systems in Table 5 shows that no coefficient of the individual HRM practices is larger than the coefficient of HRM system 3 or 4.

5.5 EFFECTS OF COMBINATIONS OF GROUPS OF HRM PRACTICES

In a further step, we wanted to investigate the effect of a firm adopting practices from different categories of HRM practices as defined before,⁶ for example, one practice of the category workplace organization and one of the category "working time management". To this end, we constructed four dummy variables based on the number of categories of HRM practices in which a firm has adopted practices and uses them at "high" level (for the construction of the underlying dummies, see Section 5.4): practices from only 1 category (bloc_1); practices from 2 categories (bloc_2); practices from 3 categories (bloc_3); practices from 4 categories (bloc_4). A regression on these four variables (reference group: firms without any practice at "high level) clearly shows that adopting practices in all four categories has the highest statistically significant association with innovation propensity, followed by adopting practices in three categories (see Table 6). Only adopting practices in one or two categories does not have a significant association with innovation.

These findings are a further hint for a cumulative effect of the use of HRM practices from different groups of HRM practices.

5.6 ROBUSTNESS CHECKS

We performed two robustness checks with respect to the basic results in Table 2. First, our innovation measure includes both process and product innovation. We checked whether the results differ between product and process innovations by estimating the innovation propensity separately for product and process innovations (see Table A.5). For the variables of interest we do not find any difference between product and process innovations except for the coefficient of the variable for the flexibility of the work schedule that is highly significant for process innovations but not for product innovations. Other differences are limited to the control variables, e.g., share of employees with tertiary-level education, the share of ICT investments, and demand development are only significantly associated with product innovations but not with process innovations.

Second, we conducted a robustness test of our estimates with respect to possible multicollinearity between the variables of

the same group of practices. We inserted the single practices for each of the three main groups (working time management, incentive payment schemes and workplace organization) separately in both innovation equations and estimated once more the respective models. The results of these additional estimates seem to confirm the findings in Table 2. Table A.6 in the appendix shows the results for working time management practices. Except for the part-time employment intensity whose coefficient becomes weakly significant when inserted separately into the innovation propensity equation, the results do not change. Results do not change at all when inserting the incentive pay variables separately (see Table A.7). Inserting the workplace variables separately, the only thing that changes is the coefficient for the number of hierarchical levels that becomes slightly significant for innovation propensity (see Table A.8).

4 In Table A.4 results are shown from a regression using the dummy variables (same names as the original variables in Table 2 only adding the suffix *_d*) instead of the original variables as regressors. The coefficient of further training intensity becomes strongly significant in the innovation propensity equation when using a dummy variable. Otherwise the results are quite similar to those in Table 2.

6 Category 1: workplace organization; category 2: working time management; category 3: incentive payment schemes; category 4: training intensity

5 HRM system 1:16.26%; HRM system 2: 36.40%; HRM system 3: 30.44%; HRM system 4: 16.90%.

6 SUMMARY AND CONCLUSIONS

Our investigation refers to the effects of 12 HRM practices on innovation performance that are grouped in four categories (workplace organization, working time management, incentive payment schemes and training). We find that variables representing workplace organization (with the exception of the var-

iable for the decrease of the number of hierarchical levels) show highly significantly positive associations with innovation propensity. Some of them seem to be more important than other "standard" determinants of innovation such as demand development, competition conditions or human capital endowment. New workplace organization practices are also important for innovation success, however, their effects on innovation success are more limited than for the propensity of innovation. A further finding is that the intensity of further training is significantly positively associated with innovation success, but not with innovation propensity. Working time management practices and incentive payment schemes appear to have only a small impact on both innovation propensity and innovation success. Overall, we find stronger linkages between innovative HRM practices and innovation propensity than with innovation success. The main reason for these differences might be the fact that the two innovation variables measure different things. HRM practices seem to be directly positively associated with the firm being innovative or not. Given that a firm is innovative, differences as to the magnitude of innovative sales might be influenced to a higher degree by a series of further factors such production and marketing skills as it is indicated by the effect of the variable intensity of further training. The relative dominance of the workplace organization practices is confirmed by the overall effects of the groups of practices as measured by the three factors that were extracted from the data by factor analysis.

Finally, we find cumulative effects of the use of HRM practices on innovation. First, from a certain threshold on, the effect on innovation is larger, the larger the number of individual practices a firm has introduced and used intensively. Second, also from a certain threshold on, the effect on innovation is larger, the larger the number of groups of practices a firm has introduced and used intensively. These cumulative effects demonstrate the potential of such practices that can be exploited by firms in order to increase their performance.

On the whole, our study contributes to literature in three ways, first, through the use of detailed information on a broad spectrum of HRM practices; second, by focusing on the effects on innovation, which is a rather under-researched topic; and third, through the identification of cumulative effects of the use of such practices on innovation. Of course, there are also drawbacks, the most important one being, as already mentioned, that we cannot identify causal links, thus, letting open the possibility that the reverse causality holds, namely that innovative firms are more likely to adopt an innovative workplace organization and not the other way around.

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