Holistic Innovation Success?

Complementarities between Flexible Workplace and Human Resource Management Practices in the Innovation Process

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Abstract

Flexible workplace and HRM practices are regarded as one way to booster the innovation capacity of establishments. This paper investigates the nexus between flexible workplace and HRM practices on the one hand and the innovation propensity of establishments on the other. To this aim a variety of econometric models are estimated using the IAB establishment panel dataset collected by the German federal employment office. The results indicate that flexible workplace and HRM practices have a considerable innovation enhancing impact and that there are complementarity effects between these practices which have to be taken into account. By conducting several simulations we are furthermore able to quantify these benefits in monetary terms.

JEL classification: C21, C25, D21, D23, M12, O32
Keywords: Innovation, flexible workplace and HRM practices, trivariate Probit and multinomial Logit models

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1 Introduction

There is no doubt that innovations are a key factor for the future competitiveness and success of a single firm as well as for the economy as a whole. If one looks at the innovation capacity of German establishments, a disillusioning impression looms. The share of establishments e.g. which have introduced product innovations has decreased markedly over the last years. In this context the number of premonitory contributions rises which criticize the slackness of German establishments and ask for more flexibility and creativity.

One way out of this trap is the cutback of innovation restrains by implementing modern and flexible forms of workplace and human resource management (HRM) practices. These organizational changes can be characterized as a move away from the traditional "Tayloristic" organization with its strong centralization of decision authority and its narrowly defined occupations. Instead, more and more establishments began to implement flexible workplace practices which are aimed at "empowering" their employees by giving them more responsibility in a more flexible and less hierarchical environment. Such a "Holistic" organization of work, however, needs to be complemented by flanking HRM practices. There are a number of reasons indicating complementarities between different workplace and HRM practices. An obvious example is the necessity to offer employees training measures in connection with job rotating programmes. Implementing one single measure in isolation thus would lead to a suboptimal result as compared to the implementation of a coherent bundle of practices.

The aim of this study is to investigate the nexus between such flexible workplace and HRM practices on the one hand and the innovation propensity of establishments on the other, i.e. we seek to give an answer to the question whether more innovative establishments regarding their workplace and HRM practices are also more successful in implementing innovations. Thereby we will pay special attention to possible complementarities between different workplace and HRM practices. We will estimate a variety of econometric models by using a representative dataset for Germany, namely the IAB establishment panel dataset. This paper therefore will add one more piece of evidence to the ongoing debate about the impact of flexible workplace and HRM practices.

We proceed as follows: In the next section we briefly sketch the development of the innovation behaviour in Germany during the last years. Section three is devoted to flexible workplace and HRM practices. We present some descriptive results about the implementation and diffusion of such practices and examine some first links between such practices and the innovation behaviour of German establishments. In section four we will present two econometric models, namely a trivariate Probit and a multinomial Logit model and discuss the estimation results. Section five formulates some policy implications while section six concludes and gives some outlook for further research in this area.

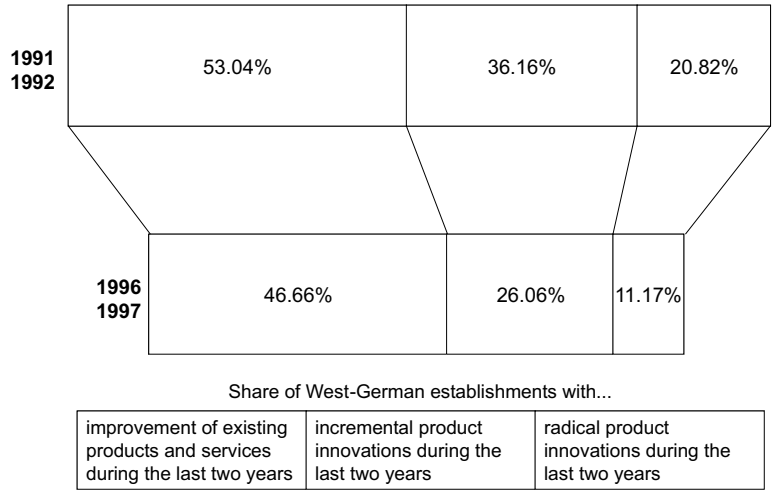
2 Innovation Behaviour in Germany

In the following we will present some first stylized facts about the innovation behaviour of German establishments. Thereby we revert to the IAB establishment panel which represents a yearly survey of the demand side situation of the labour market.[1] The unit of interest is the establishment, i.e. the local unit where the activity of a company takes place. The basis for the IAB establishment panel is the employment statistics register of the Federal Employment Office ('Bundesanstalt für Arbeit'), where employers have to report information regarding their employees subject to a social compulsory security

[1] For a more thorough discussion see Kölling (2000) or Bellmann and Kölling (2000).

scheme. Starting from this register a stratified representative sample is drawn. The IAB panel started in 1993 with about 4,200 establishments from West-Germany. Since 1996 establishments from East-Germany are also included in the data set that in 1998 contained about 10,300 units.

Figure 1: Innovation behaviour of West-German establishments



The IAB panel is organized in a modular form. There are topics covered annually like changes in the level and structure of employment and questions about the company´s policy, e.g. information about the business volume and investment. Other topics are only covered irregularly, particularly information about innovations which are at our disposal for the years 1993 and 1998. In this context the following questions were posed:

- Has your establishment improved an already offered product or service during the last two years? (*Improvement*)
- Has your establishment included a new product or service in its range of products during the last two years that already existed in the market? (*Incremental*)
- Has your establishment included a new product or service in its range of products during the last two years that were new for the market? (*Radical*)

Looking at the share of establishments which have introduced the various forms of innovation reveals that the innovation activity of West-German establishments has decreased considerably between 1991/1992 and 1996/1997 (see figure 1). The share of establishments which have introduced radical product innovations decreased by 9.65% from 20.82% to 11.17%. Improvements and incremental product innovations decreased by about the same magnitude.

This negative impression does not change if one differentiates between various size classes or different industry sectors. The figures in table 1 disclose on the one hand that larger establishments are also the more innovative ones, e.g. the share of establishments with more than 500 employees which have either improved an existing product/service or introduced an incremental or even a radical product innovation amounts to 77.37% in 1991/1992, while the same figure for small and medium sized establishments (SME) with 5 to 500 employees amounts to 56.93%. On the other hand these figures also show that the innovation activity has dropped considerably from 1991/1992 to 1996/1997 across all size groups. Only 74.25% of all large establishments and 51.97% of all SME were still innovative in the years 1996/1997, a decrease of 3.12% and 5.96%, respectively.

Table 2 contains the same figures for different industry sectors: The industrial, service and industry related service sector. The first contains establishments in the primary, investment goods and consumer goods industry. The service sector is made up of establishments which belong to one of the following areas: Whole- and retail sale, financing and insurance, transportation and telecommunication, legal advice, consulting, accounting, architecture and engineering. Finally, we excluded whole- and retail sale establishments, i.e. the only distributive part of the service sector, out of the service sector to obtain an industry related service sector. Although there are again considerable differences, with the industry as the most innovative sector, the general picture of decreasing innovations still remains.

East-German establishments are only included since 1996 in the IAB panel, thus we are not able to depict their dynamic innovation behaviour but only compare them with West-German establishments for the years 1996/1997. Table 3 replicates the well known fact that East-German establishments as compared to their West-German counterparts are still in an inferior position regarding their innovation behaviour.

This disillusioning empirical picture that we sketched for the time period until 1998 does not improve even in the following years. According to a study recently presented by the ifo institute for economic research (see Penzkofer (2003)), the share of innovative establishments in the industry sector changed only slightly during the period from 1997 to 2000.[2] This share, however, dropped markedly after 2000 from 58.6% to 54.1% in 2001 and 53.0% in 2002. Studies conducted at the Center for Economic Research (see e.g. Janz, Ebling, Gottschalk, Peters, and Schmidt (2002)) arrive at a similar conclusion. They report that the share of innovative establishments in the industrial sector dropped from 67% in 1999 to 62% in 2000 and in the service sector from 63% to 60%. Recently the European Commission (2002) presented a study which attested that German establishments only take a middle rated position among all European countries, the United States and Japan. Since there is no doubt that innovations are a key factor for the future success of a single establishment as well as for the economy as a whole, these premonitory signals have to be taken seriously. In order to foster the innovation process, however, first of all one has to understand the determinants of this process.

In this context a variety of theoretical and empirical contributions have emerged. Traditional 'Schumpeterian' explanations emphasize the role of the size of establishments and the market structure and argue that especially larger firms with a high market power are capable of carrying out successful innovation activities.[3] Other studies in this context assume the existence of a 'knowledge function' where input factors like e.g. expenditures for R&D create patents and product innovations as an output.[4] Additional determinants that have often been considered in the literature are financial constraints (Harhoff (1996)), export activities (Ebling and Janz (1999)) and public R&D subsidies (Beise and Stahl (1998) or Czarnitzki and Fier (2002) (2002)).[5] Equally important factors are the human capital of establishments and the creativity of their employees.[6] To fully exploit the

[2]Innovative establishments are thereby defined as establishments which have either introduced a new product/service (product innovation) or conducted a process innovation, i.e. implemented a new and more efficient manufacturing method or production process.

[3]For an empirical study on the impact of the market structure on product and process innovations in Germany see e.g. Flaig and Stadler (1994) or François, Favre, and Negassi (2002) for France.

[4]See e.g. Griliches (1990) who finds that R&D expenditure has a significant impact on innovation or Hall, Griliches, and Hausman (1986).

[5]For a review of the various determinants of the innovation process see e.g. Cohen (1995).

[6]Lee, Florida, and Gates (2002) recently have analyzed which role the diversity of the local environment plays in the production of innovation. Their findings suggest that innovation at the regional level is positively associated with human capital and creativity.

Table 1: Share of West-German innovative establishments for different size classes

	1991/1992			1996/1997		
	≤ 5 employees	5-500 employees	> 500 employees	≤ 5 employees	5-500 employees	> 500 employees
Improvement	22.72%	46.82%	76.87%	19.60%	45.54%	74.38%
Incremental	19.55%	34.50%	45.82%	14.69%	26.34%	35.27%
Radical	9.39%	17.74%	31.21%	6.58%	9.98%	19.10%
Innovative at all	30.92%	56.93%	77.37%	14.91%	51.97%	74.25%

Table 2: Share of West-German innovative establishments for different industry sectors

	1991/1992			1996/1997		
	Industry sector	Service sector	Industry related services	Industry sector	Service sector	Industry related services
Improvement	76.16%	46.16%	61.09%	70.29%	40.97%	48.56%
Incremental	42.81%	42.93%	38.39%	33.52%	29.26%	28.69%
Radical	30.52%	19.53%	20.99%	17.52%	11.33%	10.88%
Innovative at all	80.38%	58.92%	62.23%	74.47%	49.63%	52.61%

Table 3: Share of innovative West- and East-German establishments in 1996/1997

	Germany	West-Germany	East-Germany
Improvement	39.64%	46.66%	33.43%
Incremental	24.74%	26.06%	23.57%
Radical	9.46%	11.17%	7.94%
Innovative at all	41.51%	46.21%	37.22%

potential of high qualified employees, however, an appropriate workplace organization is needed. Thus more and more establishments recently introduced workplaces with a higher degree of functional flexibility and responsibility. In the following sections we will give an overview of the adoption of flexible workplace and HRM practices and try to assess their impact on the innovation process.

3 Workplace and HRM Practices

The eighties have experienced a boom in the field of popular management theory. Examples include the influencing work of Tom Peters and Robert Waterman (1982) "In search of Excellence" or Peter Drucker´s and Rosabeth Moss Kanter´s idea of "Empowerment". The upshot of these ideas was a call against overflowing tendencies of bureaucracy and centralization which more and more conflicted with the capacity of establishments to react quickly to changing economic circumstances and repressed their innovation capacity. Instead, companies were asked to decentralize decision authority and to "empower" their employees by giving them more responsibility with lower restrictions and incentives to become more productive. All these changes in the workplace organization – more flexibility, more responsibility and less hierarchy – can be characterized as a move away from the traditional and centralistic 'Tayloristic' organization and have become known under the notion of 'holistic organization' or 'high-performance workplaces'.

There is a large theoretical literature on the determinants of such organizational changes.[7] Lindbeck and Snower (1995, 2000) have developed a theoretical model with four major forces driving organizational changes: Increasing investments in more versatile capital, increasing investments in information and communication technology (ICT), more qualified work force and changing preferences in favor of versatile work. All these forces improve the trade-off between increasing rates of return from specialization in 'Tayloristic' organizations and rates of return from task complementarities in 'Holistic' organizations and thus also increase the probability to introduce more flexible workplace practices.

With the introduction of such organizational changes, however, the insight began to grow that to fully exploit the benefits of changes in the organization of work, they have to be complemented by appropriate human resource management measures.[8] Only to implement workplaces with more responsibility and decision authority e.g. and not complement these changes with a payment system which offers the individual employees incentives to exploit the offered scopes, may result in suboptimal results compared to the case where they were introduced in combination. Another persuasive example is the

[7] For an empirical verification of the Lindbeck/Snower model see Fier and Harhoff (2001).

[8] See e.g. Ichinowski, Shaw, and Prennushi (1997), Doeringer, Evans-Klock, and Terkla (1998) or Ichinowski, Kochan, Levine, Olson, and Strauss (1996).

following: Employees which worry about loosing their jobs have only a limited interest in making productivity enhancing proposals which could rationalize their own jobs. If the relationship between the management and employees, however, is characterized by mutual trust, then again these changes may have the desired influence. In the following we will pay special attention to such complementarities between flexible workplace and HRM practices. Table 4 contains a description of the variables we have at hand to measure flexible workplace and HRM practices.[9]

Table 4: Flexible workplace and HRM practices

Topic	Description of the variable
Workplace practices	
Flexibility	Decentralization of responsibilities and decision-authority
Team work	Introduction of group-workplaces with own responsibilities
Responsibility	Introduction of units with own costing and result calculation
Job rotating	Costs for training and education for job rotating covered by employer for job rotation
Human resource practices	
Hiring practices	Plans for manpower requirements set out in writing
	Formal plans for staffing existing
	Formal job description existing
	Assessment of job performance set out in writing
Layoff practices	Employees laid off as a reaction to decreasing sales in the past
Job security	Problems expected by the employer due to a too high workforce
	Problems expected by the employer due to a high labour turnover
	Number of layoffs relative to total number of employees
Flexibility	Number of part-time employees relative to total number of employees
	Number of workers on temporary loan relative to total number of employees
Mutual trust	Workers council existing
Incentive payment	Profit participation plans
	Wages above collective wage agreement
Training	Company finances educational and vocational training
	Number of employees sent to educational or vocational training relative to total number of employees

There are a number of empirical studies which analyzes complementarities between organizational changes and other input factors like e.g. investments in information and communication technology, capital and labour. They find empirical evidence for a significant leverage effect of organizational changes.[10] These papers mainly focus on the impact of organizational changes on the productivity of establishments or the labour demand.[11] The number of studies which try to quantify the impact of flexible workplace and HRM practices on the innovation capacity of establishments, on the other hand, is rather small.

[9] This classification closely corresponds to the one used by Ichinowski, Shaw, and Prennushi (1997) in their seminal paper on the effects of HRM practices on the productivity.

[10] See e.g. Hitt and Snir (1999) or Bresnahan, Brynjolfsson, and Hitt (1999).

[11] See e.g. for Germany Wolf and Zwick (2002), for the United States Black and Lynch (2001) or for Denmark Lundvall and Kristensen (1997). For the skill biased organizational change hypothesis see e.g. Falk (1999) or Hujer, Caliendo, and Radić (2002).

One exception is the paper by Michie and Sheehan (2000) who use the workplace industrial relations survey for the United Kingdom and were able to show that more flexible HRM practices are positively correlated with increasing investment in R&D. François, Favre, and Negassi (2002) conducted a similar analysis for France and demonstrated that the effects of organizational factors are even more important than the usually considered factors like size of the establishment and market structure. Recently Ernst (2003) presented a study where he analyzed the impact of organizational culture on the innovation performance of German establishments. He found that innovation-enhancing cultures have a positive impact on innovation success, whereas the effect of hierarchical cultures is negative.[12]

This paper aims at adding one more piece of empirical evidence to the ongoing discussion about the impacts of flexible workplace and HRM practices on the innovation capacity of establishments. In the following we will first of all derive some stylized empirical facts about the diffusion of such practices among German establishments before presenting an empirical strategy how to take the complementarities between these practices into account and presenting some first simple descriptive statistics which point to a possible link to innovations. The interested reader can find several figures in the appendix which are intended to give him a first impression about the presence and diffusion of flexible workplace practices over time, for different size classes, different industry sectors and separated for West- and East-German establishments.[13] Instead of presenting them in the text, we will summarize the most important empirical patterns:

- The number of establishments which have introduced flexible workplace practices has declined over time.
- Most of these practices are introduced in the industry sector, followed by the sector of industry related services and the service sector.
- The size of the establishment is positively correlated with the propensity to introduce such practices.
- West-German establishments are more likely to implement flexible workplace practices than their East-German counterparts.

We already indicated that there are a couple of theoretical reasons to believe in the existence of complementarities between the introduction of flexible workplace and flanking HRM practices. Indeed, the major focus of this paper lies in the assessment and quantification of such complementarities. However, the empirical implementation faces one major problems. The most obvious proceeding would consist in running a regression with an appropriate innovation indicator as the dependent variable and all dummy variables indicating the presence of flexible workplace and HRM practices as independent variables. In order to test the complementarity hypothesis explicitly, all possible interaction terms had to be included, too. In our case the number of exogenous variables therefore would amount to 19 dummy variables indicating the implementation of flexible workplace and HRM practices in isolation and 171 interaction terms to test if there are complementarities between two different practices, respectively. The high degree of multicollinearity between these practices makes such a proceeding, however, impossible.[14] As an alternative we seek to identify common clusters of establishments

[12]It should be mentioned that there are a number of papers which analyze optimal organizations from a more business oriented perspective. Examples for Germany include Albers and Eggers (1991) which analyze the so called "loose-tight principle" of organization.

[13]Unfortunately most of the questions referring to HRM practices were only posed in 1998 so that we are not able to figure out the diffusion of these practices over time.

[14]The appendix contains the correlation matrix for the different flexible workplace and HRM practices.

and conduct the econometric analysis with these cluster dummy variables as explanatory variables.[15] Each cluster should contain establishments which are similar regarding their workplace and HRM practices whereas the clusters themselves should be as heterogenous as possible. One standard method in this context is a cluster analysis. The interested reader can find the technical details of this cluster analysis in the appendix. At this point it is suffice to notice that applying such a cluster analysis yields two clusters of establishments.

In addition we also applied an alternative strategy to identify different establishment clusters by constructing an HRM-index. This HRM-index simply consists of the sum of implemented flexible workplace and HRM practices, i.e. establishments which have implemented more practices are assigned to a larger HRM-index and vice versa.[16] Different clusters of establishments were derived by partitioning them in four 25%-percentiles, respectively. This HRM-index is straightforward to interpret. For example, $HRM_1 = 1$ indicates that an establishment belongs to the lowest quartile of the least flexible establishments, whereas $HRM_4 = 1$ indicates the affiliation of the establishment to the top 25% of the most flexible establishments. Table 5 shows how these clusters constructed by using this HRM-index and the results of the cluster analysis differ from each other. One can clearly recognize that the HRM_4 cluster is the most innovative one regarding flexible workplace and HRM practices. For example, nearly 56% of all establishments belonging to this cluster decentralized their decision authority as compared to only 3.6% of all establishments in the lowest HRM_1 cluster. HRM_4 establishments are additionally more likely to introduce group-workplaces, offer their employees more responsibility and the possibility of job rotation. These establishments also feature a lower churning rate as indicated by the number of layoffs relative to the total number of employees and make more extensive use of temporary employment relations. Interestingly, the share of establishments expecting problems due to a too high labour workforce is higher among them, too. The differences in the shares between the two groups $Cluster_1$ and $Cluster_2$ are also pronounced.

The scattergram in figure 2 gives a graphical summarization of how the different clusters of establishments differ from each other. On the x-axis we depicted the sum of the implemented flexible HRM practices and on the y-axis the sum of the implemented flexible workplace practices. One can again recognize that HRM_1, HRM_2 and $Cluster_1$ establishments are the least flexible ones regarding workplace and HRM practices while HRM_4 and $Cluster_2$ establishments are the most innovative ones. HRM_3 establishments are somewhere between these two polar cases.[17]

An interesting question at this point is whether establishments with flexible workplace and HRM practices differ in their innovation behaviour. To this aim we divided the establishments in those which have either improved an already existing product/service or even introduced an incremental or radical product innovation and those which have not. The following figure 3 shows the position of these establishments in the workplace-HRM scattergram. This scattergram clearly points to the close relationship between flexible workplace, HRM practices and innovations. Those establishments with higher

[15] For a similar proceeding see Ichinowski, Shaw, and Prennushi (1997) who identified clusters of establishments by "inspection" and additionally also applied a variety of statistical nominal scaling procedures. Wolf and Zwick (2002) conducted a factor analysis to overcome the multicollinearity problem.

[16] It should be noted that some variables indicate the opposite of flexible HRM practices, e.g. if there are problems expected by the employer due to a high workforce or due to a high labour turnover or the fraction of layoffs relative to the total number of employees. These variables therefore enter the sum with a negative sign.

[17] Note that since some practices enter the score of HRM practices with a negative sign, the total sum can also become negative.

Table 5: Share of establishments with introduced flexible workplace and HRM practices

	All	HRM_1	HRM_2	HRM_3	HRM_4	$Cluster_1$	$Cluster_2$
Workplace practices							
Decentralization of responsibilities and decision-authority	23.65%	3.56%	10.54%	24.79%	55.69%	10.21%	42.08%
Introduction of group-workplaces with own responsibilities	16.55%	2.27%	6.14%	14.43%	43.34%	6.15%	30.8%
Introduction of units with own costing and result calculation	14.06%	2.07%	6.21%	13.46%	34.48%	5.93%	25.2%
Costs for training and education for job rotation covered by employer	9.53%	0.06%	2.59%	7.38%	28.07%	2.04%	19.79%
Human resource practices							
Plans for manpower requirements set out in writing	35.3%	2.39%	15.01%	47.18%	76.58%	7.52%	73.38%
Formal plans for staffing	36.91%	3.24%	18.24%	47.64%	78.53%	8.62%	75.72%
Formal job description	44.69%	6.54%	29.75%	61.55%	80.92%	18.85%	80.13%
Assessment of job performance set out in writing	34.28%	5.05%	16.82%	41.94%	73.29%	10.6%	66.74%
Employees laid off as a reaction to decreasing sales in the past	8.67%	14.24%	8.02%	6.54%	5.89%	9.26%	7.86%
Problems expected due to a too high workforce	21.42%	15.08%	19.15%	25.57%	25.87%	12.39%	33.79%
Problems expected due to a high labour turnover	2.62%	2.01%	2.72%	3.17%	2.59%	2.35%	2.99%
Number of layoffs relative to total number of employees in 1998	4.11%	13.41%	2.19%	1.08%	0.71%	6.6%	0.93%
Number of part-time employees relative to total number of employees in 1998	17.96%	9.81%	19.64%	21.71%	19.87%	20%	15.37%
Number of workers on temporary loan relative to total number of employees in 1998	0.59%	0.02%	0.158%	0.35%	1.77%	0.47%	0.75%
Workers council existing	50.35%	7.32%	36.02%	67.39%	85.02%	20.19%	88.7%
Profit participation plans	10.71%	0.97%	3.36%	9.13%	29.37%	3.5%	20.6%
Wages above collective wage agreement	33.84%	26.13%	30.78%	28.77%	43.75%	36.18%	32.01%
Company finances educational and vocational training	69.4%	17.9%	70.38%	90.99%	98.25%	49.78%	96.31%
Number of employees sent to educational or vocational training relative to total number of employees in 1998	22.81%	2.65%	18.24%	26.94%	43.4%	16.79%	31.06%
Total number of establishments	6,182	1,545	1,546	1,545	1,546	3,575	2,607

scores in both dimensions are also the more innovative ones.

Figure 2: Clusters of establishments

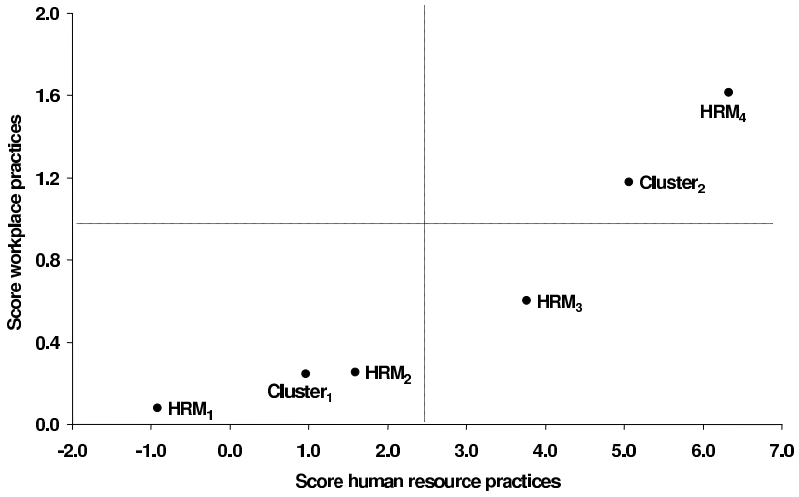
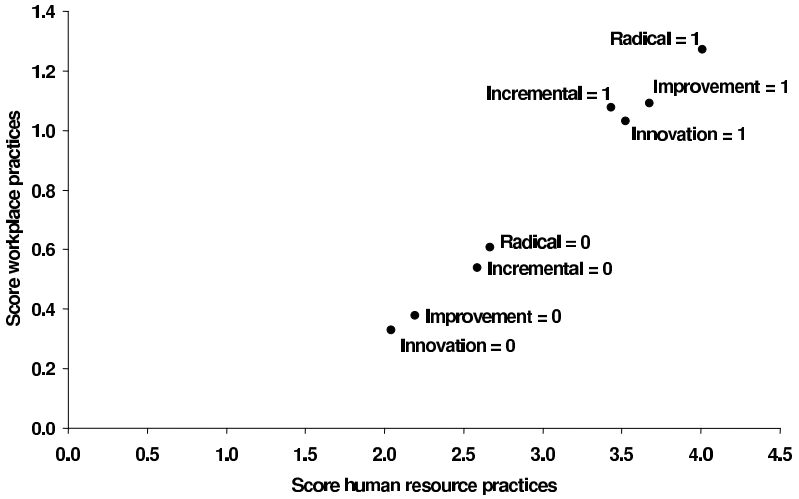


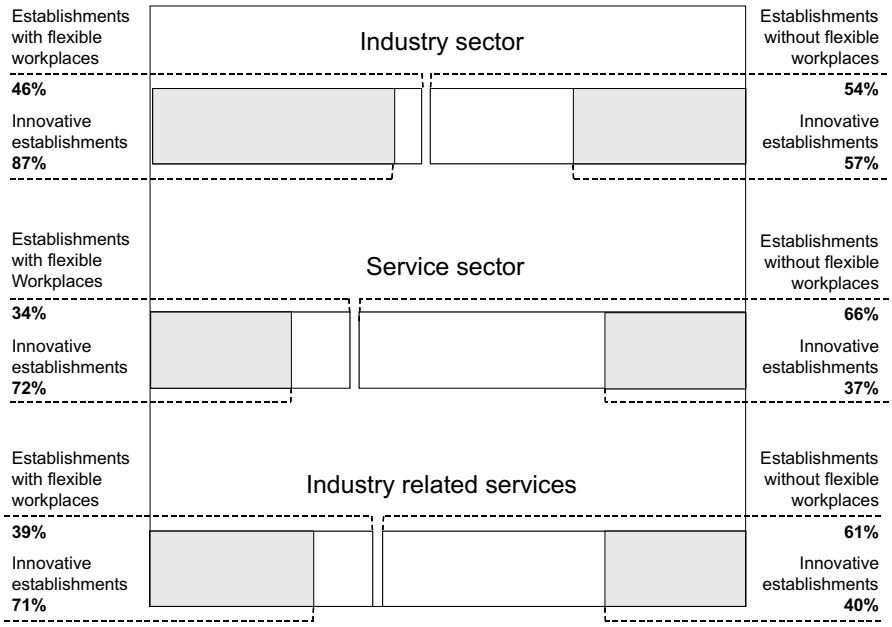
Figure 3: Clusters of innovative establishments



Another piece of evidence for a positive link between introduced organizational changes and a higher innovation propensity can be obtained if one poses the following question: Is the fraction of innovative establishments larger among those establishments which have implemented flexible workplace practices as compared to those establishments

which have not? Figure 4 contains the answer to this question differentiated for different industry sectors. Looking at this figure one can first of all realize that the share of establishments which have introduced at least one of the flexible workplace practices listed in table 4 is largest in the industry sector, followed by the industry related service sector and finally the service sector. One can also clearly see that the share of innovative establishments is larger among those which have introduced flexible workplace practices compared to those which have not. In the following we will see whether these first simple descriptive hints are confirmed by the econometric estimation results.

Figure 4: Innovation and flexible workplace practices



4 Econometric Modelling and Estimation Results

In the following we will estimate two econometric models in order to test and quantify the effects of flexible workplace and HRM practices on the innovation propensity of establishments. Thereby we concentrate on establishments which participated in 1998 in the IAB establishment panel, i.e. due to fact that the information about the innovation behaviour refer to the last two years, our dependent variable is the innovation behaviour of West- and East-German establishments for the years 1996/1997. As mentioned previously, establishments were asked if they have improved an already existing product/service, introduced a product/service which was new for the own establishment but not new for the market (incremental product innovation) or if the innovation was a radical one, i.e. consisted of a product/service for which a new market had to be created. At first we will model these three decisions separately but allowing correlations between them by employing a trivariate Probit model. One advantage of this model as compared e.g. to an ordered Probit model is that it takes the heterogeneity of the parameters into account, i.e. it assumes that the effects of flexible workplace and HRM practices may be different for the different decisions at hand. One disadvantage, however, is the fact that we are not able to take overlapping decisions into account, e.g. if an establishment not only improves an already existing product/service but additionally introduces an incre-

mental product innovation. To meet this feature of our dataset, in the second part of this section we will estimate a multinomial Logit model. For the estimation we excluded establishments belonging to the agricultural and public sector and estimated a variety of models differing in the included exogenous variables. We started with a basic model which only includes the dummy variables indicating flexible workplace and HRM practices, i.e. the *HRM* and the *Cluster* dummy variables, respectively. In an extension to this basic model we included industry sector, regional and size class dummies and finally also other exogenous variables which might have an impact on the innovation decision of establishments.[18] In the following sections, however, due to space limitations, we will only report the estimation results of the *HRM* and *Cluster* dummy variables for the models which include the whole set of control variables.[19]

4.1 Trivariate Probit Model

In this section we will estimate the three different innovation decisions the establishment faces separately. To be more precise we will assume the following model:[20]

$$\begin{aligned} y_1 &= \begin{cases} 1 & \text{if } y_1^* = x_1'\beta_1 + \epsilon_1 > 0 \\ 0 & \text{otherwise} \end{cases} \\ y_2 &= \begin{cases} 1 & \text{if } y_2^* = x_2'\beta_2 + \epsilon_2 > 0 \\ 0 & \text{otherwise} \end{cases} \\ y_3 &= \begin{cases} 1 & \text{if } y_3^* = x_3'\beta_3 + \epsilon_3 > 0 \\ 0 & \text{otherwise} \end{cases} \end{aligned} \tag{1}$$

where y_1 equals one if an establishment improves an already existing product/service and y_2 (y_3) equals one if the same establishments introduces an incremental (radical) product/service. Regarding the error terms we make the following assumptions:

$$\epsilon = \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \end{pmatrix} \sim N(0, \Sigma). \tag{2}$$

We therefore allow these three seemingly unrelated equations to be connected via possible correlations in the covariance matrix Σ. For reasons of identification we restrict the variances of the three Probit equations to be equal to one. The likelihood function of model (1) is given by:

$$L = \prod p(Y_1 = y_1, Y_2 = y_2, Y_3 = y_3 | x_1, x_2, x_3, \Sigma) \tag{3}$$

where the probabilities that enter the likelihood function, e.g. $p(y_1 = 1, y_2 = 1, y_3 = 1|x_1, x_2, x_3, \Sigma) = p(\epsilon_1 > -x_1'\beta_1, \epsilon_2 > -x_2'\beta_2, \epsilon_3 > -x_3'\beta_3) = p_{111}$, take on forms similar to the following:

$$p_{111} = \int_{-x_1'\beta_1}^{+\infty} \int_{-x_2'\beta_2}^{+\infty} \int_{-x_3'\beta_3}^{+\infty} \phi_3(\epsilon_1, \epsilon_2, \epsilon_3 | x_1, x_2, x_3, \Sigma) d\epsilon_1 d\epsilon_2 d\epsilon_3. \tag{4}$$

[18] The included variables are: Share of blue and white collar employees for qualified tasks, existence of an R&D and market research department, engagement in R&D cooperations with other institutions like e.g. universities, indicators for the competition pressure, state of the technology and profitability, investments in ICT and dummy variables indicating different legal forms.

[19] The complete estimation results are available from the authors on request.

[20] We assume a representative establishment and therefore skip the i subindex for notational convenience.

The practical obstacle lies in the evaluation of the three-dimensional integral in (4) with $\phi_3(\cdot)$ as the trivariate normal density function. A solution to this problem is to use simulation methods to approximate this integral. One algorithm that has been found to be fast and accurate in this context is the GHK smooth recursive simulator. Its basic idea will be summarized in the following.[21]

Our aim is to evaluate expressions like the following:

$$p_{111} = p(\epsilon_1 > -x_1'\beta_1, \epsilon_2 > -x_2'\beta_2, \epsilon_3 > -x_3'\beta_3) \tag{5}$$

where the ϵ's are distributed as given in (2). The probability in (5) can be rewritten as a product of one unconditional and two conditional probabilities according to:

$$p(\epsilon_1 > -x_1'\beta_1)p(\epsilon_2 > -x_2'\beta_2|\epsilon_1 > -x_1'\beta_1)p(\epsilon_3 > -x_3'\beta_3|\epsilon_2 > -x_2'\beta_2, \epsilon_1 > -x_1'\beta_1). \tag{6}$$

Since Σ is a positive definite matrix using the Cholesky decomposition, a lower triangular matrix Λ can be found such that: $\Lambda\Lambda' = \Sigma$. Defining:

$$\nu = \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix} \text{ with } \nu \sim N(0,1) \tag{7}$$

we can rewrite ϵ as $\epsilon = L\nu$ and arrive at the following relation between the ϵ's and the ν's:

$$\begin{aligned} \epsilon_1 &= \lambda_{11}\nu_1 \\ \epsilon_2 &= \lambda_{12}\nu_1 + \lambda_{22}\nu_2 \\ \epsilon_3 &= \lambda_{13}\nu_1 + \lambda_{23}\nu_2 + \lambda_{33}\nu_3 \end{aligned} \tag{8}$$

where λ_{ij} is the (i,j)-element in the Λ matrix. Using these relations, the product of unconditional and conditional probabilities in (6) can equivalently be written as:

$$\begin{aligned} p_{111} = \; & p\left(\nu_1 > \frac{-x_1'\beta_1}{\lambda_{11}}\right) \\ & p\left(\nu_2 > \frac{-x_2'\beta_2 - \lambda_{12}\nu_1}{\lambda_{22}} \,\middle|\, \nu_1 > \frac{-x_1'\beta_1}{\lambda_{11}}\right) \\ & p\left(\nu_3 > \frac{-x_3'\beta_3 - \lambda_{13}\nu_1 - \lambda_{23}\nu_2}{\lambda_{33}} \,\middle|\, \nu_1 > \frac{-x_1'\beta_1}{\lambda_{11}}, \nu_2 > \frac{-x_2'\beta_2 - \lambda_{12}\nu_1}{\lambda_{22}}\right). \end{aligned} \tag{9}$$

The advantage of (9) as compared to (6) is the fact that the ν's are independent normal distributed random variables and hence the probability p_{111} which we want to evaluate can be equivalently expressed as a product of independent but conditioned univariate cumulative density functions.

Assume now that ν_1^* and ν_2^* are realizations taken from truncated normal distributions with lower truncation points $\frac{-x_1'\beta_1}{\lambda_{11}}$ and $\frac{-x_2'\beta_2 - \lambda_{12}\nu_1}{\lambda_{22}}$, respectively. Drawing samples from these truncated normal distribution ensures that the conditioning of the probabilities in (9) and therefore also in (6) is taken into account. Plugging ν_1^* and ν_2^* into (9), we can rewrite this expression as a product of only unconditional, univariate and independent

[21] For an introduction see Greene (2003) or McFadden and Ruud (1994). The estimation was done using the triprobit procedure in STATA written by Antoine Terracol.

probabilities:

$$
\begin{aligned}
p_{111} &= p\left(\nu_1 > \frac{-x_1'\beta_1}{\lambda_{11}}\right) \\
&\quad p\left(\nu_2 > \frac{-x_2'\beta_2 - \lambda_{12}\nu_1^*}{\lambda_{22}}\right) \\
&\quad p\left(\nu_3 > \frac{-x_3'\beta_3 - \lambda_{13}\nu_1^* - \lambda_{23}\nu_2^*}{\lambda_{33}}\right).
\end{aligned} \tag{10}
$$

The GHK simulator now generates a series of $d = 1, \ldots, D$ random observations of ν_1^{*d} and ν_2^{*d} so that the probability p_{111} that we seek for can be approximated by:

$$
\hat{p}_{111} = \frac{1}{D}\sum_{i=1}^{N} \Phi\left(\frac{x_1'\beta_1}{\lambda_{11}}\right) \Phi\left(\frac{x_2'\beta_2 + \lambda_{12}\nu_1^{*d}}{\lambda_{22}}\right) \Phi\left(\frac{x_3'\beta_3 + \lambda_{13}\nu_1^{*d} + \lambda_{23}\nu_2^{*d}}{\lambda_{33}}\right). \tag{11}
$$

All other probabilities can be calculated in an analogous way. Plugging them into the likelihood function in (3) standard maximization procedures can be applied to get estimates for the parameters.

In tables 6 and 7 we report the estimation results for the trivariate Probit model estimated using the GHK-simulator with $D = 25$ draws. As already noted, we only report the estimation results for the *HRM*-indices and the *Cluster* dummy variable. Additionally, we report the results of *LR*-tests on the significance of the industry sector, region, size class dummies and a set of other exogenous variables. Notice that we included the same set of explanatory variables in every equation, i.e. $x_1 = x_2 = x_3$.

Table 6: Estimation results for the trivariate Probit using the HRM-index

	Improvement	Incremental	Radical
HRM_2	0.158	0.227	0.509
	(0.060)	(0.064)	(0.097)
HRM_3	0.348	0.410	0.499
	(0.066)	(0.069)	(0.104)
HRM_4	0.470	0.528	0.690
	(0.074)	(0.075)	(0.108)
Correlations	ρ_{12}	ρ_{13}	ρ_{23}
	0.584	0.272	0.311
	(0.031)	(0.030)	(0.033)
LR-Overall	1,309 (0.000)	535.64 (0.000)	408.85 (0.000)
LR-Industry	143.96 (0.000)	85.21 (0.000)	41.74 (0.000)
LR-Region	22.92 (0.086)	25.76 (0.041)	23.60 (0.072)
LR-Size	33.48 (0.000)	2.10 (0.000)	0.26 (0.878)
LR-Controls	448.86 (0.000)	202.99 (0.000)	147.41 (0.000)

Note: Standard errors reported for the parameters and p-values for the *LR*-test.

In all estimated models the dummy variables indicating flexible workplace and HRM practices were found to be highly significant with a-priori expected signs. *LR*-tests reveal

Table 7: Estimation results for the trivariate Probit using the cluster dummy

	Improvement	Incremental	Radical
$Cluster_2$	0.273	0.281	0.189
	(0.055)	(0.055)	(0.070)
Correlations	ρ_{12}	ρ_{13}	ρ_{23}
	0.582	0.265	0.314
	(0.031)	(0.029)	(0.032)
LR-Overall	853.52 (0.000)	358.44 (0.000)	329.25 (0.000)
LR-Industry	154.84 (0.000)	106.66 (0.000)	54.90 (0.000)
LR-Region	25.02 (0.050)	25.18 (0.050)	20.51 (0.153)
LR-Size	39.57 (0.000)	4.30 (0.117)	3.36 (0.187)
LR-Controls	449.15 (0.000)	219.25 (0.000)	162.09 (0.000)

Note: Standard errors reported for the parameters and p-values for the LR-test.

also a significant impact of the industry sector, region, size dummies and of the other explanatory variables. By including them sequentially in the models, the impact of the dummy variables of interest still remains significant but, however, the magnitude of the parameters decreases. Looking at the estimation results reveals that the parameter vectors for the different outcome variables differ substantially. The HRM-indices have the largest impact on the introduction of radical product innovations followed by incremental innovations and improvement of already existing products and services. Thereby the HRM_3-dummy has the largest impact followed by HRM_2 and HRM_1. For the $Cluster$-variable the differences between the parameters are not so pronounced. Another distinct feature of the estimated models are the positive and significant correlations between the different equations. Not taking this covariance structure into account and simply estimating separate Probit equations therefore would lead to inefficient parameter estimates.

Once the estimated parameters are obtained a variety of marginal effects can be calculated.[22] The most obvious one is the marginal effect of a change in an exogenous dummy variable on the unconditional mean:

$$E(y_j|x) = p(y_i = 1|x) = \Phi(x_j'\beta_j), \text{ for } j = 1, 2, 3. \tag{12}$$

Tables 8 and 9 contain the marginal impacts of the HRM and $Cluster$ dummies on the decision to introduce an incremental and a radical product innovation, respectively, given that all other exogenous variables take on their mean values. Introducing more flexible workplace practices and complementing them additionally by appropriate HRM practices considerable raises the probability to introduce product innovations. The fact e.g. that an establishment belongs to the upper 25%-percentile regarding flexible workplace and HRM practices increases its unconditional probability to introduce radical product innovations by nearly 18%!

Another interesting marginal effect can be derived if one looks at the conditional mean function, e.g. at the probability to introduce an incremental or radical product

[22] See e.g. Greene (1996).

Table 8: Marginal effect on the unconditional probability to introduce incremental product innovations

Dummy variable	P(Dummy = 0)	P(Dummy = 1)	Marginal effect
HRM_2	0.221	0.294	0.073
HRM_3	0.208	0.343	0.135
HRM_4	0.199	0.376	0.177
$Cluster_2$	0.205	0.294	0.089

Table 9: Marginal effect on the unconditional probability to introduce radical product innovations

Dummy variable	P(Dummy = 0)	P(Dummy = 1)	Marginal effect
HRM_2	0.050	0.130	0.080
HRM_3	0.050	0.127	0.077
HRM_4	0.046	0.159	0.114
$Cluster_2$	0.060	0.086	0.026

innovation, given that the establishment has already improved an existing product or service:

$$E(y_j|y_1 = 1, x) = p(y_i = 1|y_1 = 1, x) = \frac{\Phi_2(x_1'\beta_1, x_j'\beta_j, \rho_{1j})}{\Phi(x_j'\beta_j)}, \text{ for } j = 2 \text{ and } 3. \qquad (13)$$

Table 10: Marginal effect on the conditional probability to introduce incremental product innovations

Dummy variable	P(Dummy = 0)	P(Dummy = 1)	Marginal effect
HRM_2	0.735	0.755	0.020
HRM_3	0.725	0.784	0.059
HRM_4	0.719	0.801	0.082
$Cluster_2$	0.718	0.772	0.054

Although somewhat smaller than the impacts on the unconditional probability, the in that way calculated marginal effects again reveal considerable positive impacts of flexible workplace and HRM-practices on incremental and radical product innovations (see tables 10 and 11). An interesting feature is that the absolute values of the conditional probabilities are by far larger for the conditional case than for the unconditional one, i.e. once establishments have already improved an existing product, the probability is quite high that they will additionally also introduce an incremental or even radical product innovation.

Table 11: Marginal effect on the conditional probability to introduce radical product innovations

Dummy variable	P(Dummy = 0)	P(Dummy = 1)	Marginal effect
HRM_2	0.629	0.655	0.026
HRM_3	0.610	0.699	0.089
HRM_4	0.602	0.720	0.118
$Cluster_2$	0.588	0.678	0.09

4.2 Multinomial Logit Model

Estimating a trivariate Probit model in the previous section enabled us to take the parameter heterogeneity regarding the different innovation decisions like improvement, incremental and radical product innovations into account. One shortcoming, however, was the non-consideration of possible overlapping decisions, e.g. the case where an establishment not only improves but also introduces an incremental or radical product innovation. Table 12 shows that only 24.04% of all establishments, if any, choose one alternative in isolation. A large share of establishments (14.15%) improve existing products/services and additionally also introduce incremental product innovations. Around 5% of all establishments in the sample even carried out all three forms of innovation. These figures make clear that it is necessary to take overlapping decisions into account.

Table 12: Overlapping innovation decisions

Innovation activity	Percentage	Dependent variable
Do nothing	53.63%	$y = 0$
Only improvement	18.52%	$y = 1$
Only incremental product innovation	4.66%	$y = 2$
Only radical product innovation	0.86%	$y = 3$
Improvement and incremental product innovation	14.15%	$y = 4$
Improvement and radical product innovation	3.05%	$y = 3$
Incremental and radical product innovation	0.51%	$y = 3$
Improvement, incremental and radical product innovation	4.62%	$y = 5$

Establishments have the choice between three independent decisions: Improvement, incremental and radical product innovations. Combining them leads us to $2^3 = 8$ disjunctive alternatives. Since the relative frequency for two alternatives, namely the introduction of radical product innovations (0.86%) and incremental and radical product innovations (0.51%) are rather small, we decided to pool them with the decision to improve and introduce radical product innovations to one single alternative. Thus the choice set reduces from eight to six different alternatives including the base category $y = 0$.

Our explanatory variables are firm specific. The most simple model that can be applied in this context is the multinomial Logit model which assumes that the probability

for an establishment to choose category $j = 0, 1, \ldots, 5$ is given by:[23]

$$p(y_i = j|x_i) = \frac{\exp(x_i'\beta_j)}{1 + \sum_{l=1}^{5} \exp(x_i'\beta_l)}, \text{ for } j = 0, 1, \ldots, 5. \tag{14}$$

Notice that for purposes of identification we have to restrict the β_0 vector to be equal to zero and hence treat $y = 0$ as the base category. Estimation of the parameters can be done using maximum likelihood methods. Table 13 and table 14 contain the estimation results for two different models. The first includes the HRM-indices as well as the complete set of control variables while the second model uses the $Cluster$-dummy instead of the HRM-indices. Except for the HRM_2-dummy variable for $y = 1$ all variables are significant with a-priori expected signs.

Table 13: Estimation results for the multinomial Logit model using the HRM-index

	$y = 1$	$y = 2$	$y = 3$	$y = 4$	$y = 5$
HRM_2	0.157	0.463	1.280	0.408	0.718
	(0.131)	(0.184)	(0.299)	(0.152)	(0.296)
HRM_3	0.491	0.764	1.437	0.865	1.079
	(0.144)	(0.212)	(0.315)	(0.161)	(0.306)
HRM_4	0.659	1.198	1.878	1.123	1.736
	(0.161)	(0.241)	(0.326)	(0.178)	(0.313)
LR-Overall	643.42 (0.00)	158.82 (0.00)	387.30 (0.00)	661.45 (0.00)	497.75 (0.00)
LR-Industry	96.79 (0.000)	42.22 (0.000)	33.51 (0.004)	98.46 (0.000)	47.04 (0.000)
LR-Region	29.99 (0.012)	20.76 (0.145)	23.51 (0.074)	16.22 (0.368)	25.89 (0.039)
LR-Size	23.85 (0.000)	3.41 (0.182)	2.70 (0.259)	10.64 (0.005)	2.76 (0.251)
LR-Controls	211.13 (00)	43.57 (0.00)	157.07 (0.00)	282.19 (0.00)	232.26 (0.00)
Hausman-test	$Y \setminus \{1\}$	$Y \setminus \{2\}$	$Y \setminus \{3\}$	$Y \setminus \{4\}$	$Y \setminus \{5\}$
χ^2-value	0.00	-6.69	0.00	-0.00	0.00
p-value	1.00	1.00	1.00	1.00	1.00

Note: Standard errors reported for the parameters and p-values for the LR-tests.

The interpretation of the parameters is not straightforward since the marginal effects are highly nonlinear functions of the estimated parameters:

$$\frac{\partial p(y_i = j)}{\partial x_i} = p(y_i = j) \left(\beta_j - \sum_{l=0}^{J} p(y_i = l)\beta_l \right), \text{ for } j = 0, 1, \ldots, 5. \tag{15}$$

Notice again that $\beta_0 = 0$. Equation (15) indicates that the signs of the individual β_j parameters do not reflect the total net-effect of the exogenous variables on the probability $p(y_i = j)$. Indeed, even if β_{jk} e.g. is positive, the net-effect of x_{ik} on $p(y_i = j)$ might be negative! Instead of interpreting the parameters as marginal effects one can consider the following log odds ratios:

$$\log \frac{p(y_i = j|x_i)}{p(y_i = 0|x_i)} = x_i'\beta_j. \tag{16}$$

[23] See e.g. Maddala (1983) or Franses and Paap (2001).

Table 14: Estimation results for the multinomial Logit model using the cluster-dummy

	$y=1$	$y=2$	$y=3$	$y=4$	$y=5$
$Cluster_2$	0.629	0.767	0.670	0.687	0.925
	(0.120)	(0.183)	(0.193)	(0.127)	(0.200)
LR-Overall	651.41 (0.00)	150.52 (0.00)	392.72 (0.00)	657.50 (0.00)	503.96 (0.00)
LR-Industry	100.34 (0.00)	50.77 (0.00)	41.47 (0.00)	113.22 (0.00)	52.96 (0.00)
LR-Region	31.62 (0.007)	19.95 (0.174)	23.15 (0.081)	17.24 (0.305)	25.68 (0.042)
LR-Size	22.81 (0.000)	3.45 (0.179)	4.12 (0.127)	13.67 (0.001)	4.01 (0.135)
LR-Controls	202.37 (0.00)	46.31 (0.00)	169.72 (0.00)	295.38 (0.00)	239.98 (0.00)
Hausman-test	$Y \setminus \{1\}$	$Y \setminus \{2\}$	$Y \setminus \{3\}$	$Y \setminus \{4\}$	$Y \setminus \{5\}$
χ^2-value	0.00	-4.21	0.00	0.00	0.00
p-value	1.00	1.00	1.00	1.00	1.00

Note: Standard errors reported for the parameters and p-values for the LR-tests.

Hence a positive β_{kj} parameter points out to a positive impact of x_{ik} on the probability to choose category j relative to the base category. In this sense all dummy variables indicating flexible workplace and HRM practices have a positive and significant impact on the probability that establishments become innovative at all compared to the alternative to do nothing.

Table 15 contains the marginal effects of the HRM and $Cluster_2$ dummy variables on the probabilities for the different alternatives according to (15) and given that all other exogenous variables take on their mean values. Again we find positive marginal

Table 15: Marginal effects for the multinomial Logit model

Dummy variable	$\Delta p(y=1)$	$\Delta p(y=2)$	$\Delta p(y=3)$	$\Delta p(y=4)$	$\Delta p(y=5)$
HRM_2	-0.015	0.010	0.061	0.031	0.019
HRM_3	0.011	0.014	0.059	0.080	0.027
HRM_4	0.007	0.026	0.078	0.094	0.053
$Cluster_2$	0.058	0.017	0.015	0.056	0.022

impacts for the HRM and $Cluster$ dummy variables for all probabilities. The only exception is the impact of the HRM_1 variable on $y=1$ which, however, did not turn out to be significant in the estimated model. By adding the appropriate probabilities one can compute that the total marginal impact of the HRM_2, HRM_3 and HRM_4 dummies on the probability to introduce an incremental product innovation amounts to: 0.08, 0.086 and 0.131, respectively.[24] The corresponding total marginal impact of the $Cluster_2$ dummy on the probability to introduce an incremental product innovation is

[24] The probability that an establishment introduces an incremental product innovation e.g. is given by the sum of the following probabilities: $p(y=2)+p(y=3)+p(y=4)+p(y=5)$.

0.037. The same exercise can be done for the marginal impacts of the HRM and $Cluster_2$ dummies for the probability to introduce radical product innovations. The results are: for $HRM_2 = 0.05$, for $HRM_3 = 0.18$, for $HRM_4 = 0.251$ and for $Cluster_2 = 0.11$. These numbers correspond by and large to the marginal impacts calculated for the trivariate Probit model.

One well known problem with multinomial Logit models is due to the fact that the log odds ratios for any two probabilities $p(y_i = j)$ and $p(y_i = k)$ are independent of the remaining alternatives. This property is known as the problem of independence from irrelevant alternatives (IIA). Intuitively, IIA means that the choice between two alternatives is not affected if not-chosen alternatives are removed from the choice set at hand. This assumption seems to be implausible in our context at first sight. The probability e.g. to introduce an incremental and a radical product innovation in combination may well be affected by the fact whether the establishment has the alternative to introduce a radical product innovation or not. In what follows we will therefore test if IIA holds for our sample and if we therefore can remain the estimation results.

IIA states that the probabilities for different alternatives do not depend on the choice set in which they are embedded, i.e. IIA assumes that relative probabilities of two alternatives remain the same whether a third alternative is included or not. One way to test this assumption therefore consists in omitting one or more alternatives, re-estimate the model and test if the parameter estimates differ substantially from each other or not. Tables 13 and 14 also contain the Hausman-tests for the different models where at each time one alternative was excluded from the choice set. For example, $Y \setminus \{1\}$ means that we have re-estimated the model after excluding category 1 out of the choice set. In all cases the differences between the restricted and unrestricted estimated parameter vector were not significantly different from zero. In some cases, e.g. where we excluded $y = 2$ from the choice set, the test statistic even is negative which is a clear sign that the IIA holds in our application.[25]

5 Some Policy Implications

This study was motivated by the alarming slow-down of the innovation capacity of German establishments. In the second section we reported a decreasing share of establishments which have improved products/services in a magnitude of 6.4% between 1991/1992 and 1996/1997. In almost the same manner the share of establishments with incremental or radical product innovations decreased by 10.1% and 9.7%, respectively. An often raised resort out of this situation refers to the crucial role of human capital and the adoption of new models of work organization which entail a rising productivity and innovation propensity. Table 16 shows how the adoption of flexible workplace and HRM practices contributes to an improving innovation position. Although the most flexible establishments regarding workplace and HRM practices were not spared by a decreasing innovation propensity, the slow-down was somehow slower among them. Indeed the share of HRM_4 establishments with product improvements even increased during the considered time period by around 2%.

These simple descriptive results are also confirmed by a variety of econometric models which we estimated in the fourth section and which demonstrated that flexible workplace and HRM practices are able to raise the innovation probability considerably. At this point a striking paradox arises.[26] There is a growing number of empirical studies, including this one, which document a positive impact of such practices on the productivity and

[25] See Hausman and McFadden (1984).

[26] See also Pil and MacDuffie (1996).

Table 16: Share of West-German innovative establishments

	Improvement			Incremental			Radical		
	91-92	96-97	Δ	91-92	96-97	Δ	91-92	96-97	Δ
HRM_1	26.0 %	20.5%	-5.5%	25.0%	11.8%	-13.2%	12.5%	2.3%	-10.3%
HRM_2	36.3%	33.7%	-2.6%	27.3%	16.5%	-10.8%	12.7%	7.1%	-5.7%
HRM_3	55.1%	51.6%	-3.5%	36.6%	26.2%	-10.4%	17.1%	10.4%	-6.7%
HRM_4	71.5%	73.5%	2.1%	44.1%	37.9%	-6.2%	27.6%	19.8%	-7.8%
$Cluster_1$	32.7%	29.6%	-3.1%	27.3%	17.3%	-10.0%	13.0%	5.8%	-7.2%
$Cluster_2$	68.8%	68.4%	-0.4%	42.2%	33.1%	-9.1%	24.5%	16.7%	-7.8%

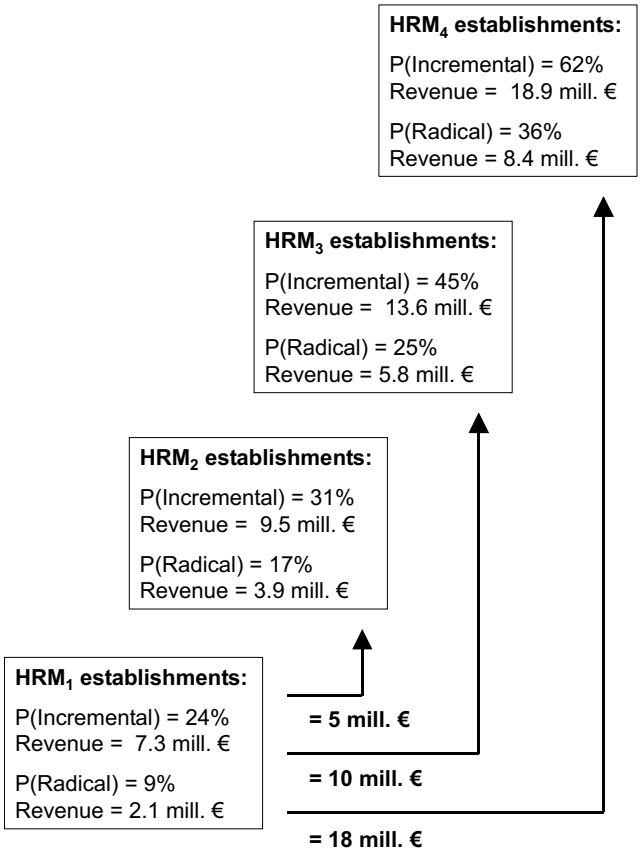
also the innovation capacity. Therefore, in reality we would expect to observe a growing number of establishments which adopt such practices. In section three, however, we presented empirical evidence that the propensity to introduce such practices has decreased considerably over the last years. One explanation for this reluctant adoption of such practices lies in the costs incurred with such changes in the short run while the benefits are only gained in the long run. Such costs may be responsible that establishments do not implement optimal practices and remain in their existing suboptimal routines. Pil and MacDuffie (1996) refer to this phenomenon as a "competence trap" and stress the importance of "windows of opportunities" which make the implementation of various organizational changes more likely.

Referring to this cost argument, we conclude this paper by presenting some calculations which monetize the benefits of flexible workplace and HRM practices. The establishments in our sample reported average revenues amounting to 277,613,000 €. The share of revenues induced by incremental and radical product innovations is on the average 10.91% and 3.37%, respectively. Using the estimated marginal effects of the HRM-dummies obtained from the trivariate Probit model in the previous section, in the following we calculated the average probabilities for incremental and radical product innovations and the expected revenues generated by them for the different HRM-clusters of establishments. Looking at figure 5 one can see e.g. that the probability to introduce incremental (radical) product innovations for HRM_1-establishments, i.e. for the least flexible ones, amounts to around 24% (9%) with corresponding revenues of 7.3 (2.1) mill. €. In contrast, the most flexible establishments, i.e. those belonging to the top 25%-percentile, feature probabilities for introducing incremental and radical product innovations which amount to 62% and 36%, respectively. These increasing probabilities due to the introduction of organizational changes are also reflected in higher revenues of 18 mill. €. It is left to every establishment to decide whether these benefits outweigh the costs associated with the introduction of flexible workplace and HRM practices. With this paper, however, we were able to show that they exist.

6 Conclusions and Outlook

The aim of this study was to investigate and quantify the nexus between flexible workplace and HRM practices on the one hand and the innovation propensity of German establishments on the other. In this context we were especially interested in possible complementarities between different flexible workplace and HRM practices. In order to test this complementarity hypothesis, we first of all conducted a cluster analysis and

Figure 5: Benefits associated with flexible workplace and HRM practices



constructed an appropriate index reflecting the degree of flexibility regarding workplace and HRM practices. Afterwards we examined whether there are statistically significant differences regarding the innovation propensity between these clusters of establishments by estimating multivariate and multinomial discrete choice models. The results clearly indicate that flexible workplace and HRM practices have a statistically significant effect on the innovation propensity of German establishments. In several simulation studies we were furthermore able to demonstrate that these impacts are not only statistically significant but also of considerable economic magnitude.

Although the results are very robust regarding different econometric models and specifications, there are several drawbacks and shortcomings which have to be taken into account when interpreting the results. Due to data limitations we were forced to focus on a cross section and hence were not able to take unobservable heterogeneity into account. In a recent study Beck, Brüderl, and Woywode (2002) were able to show that neglecting this unobservable heterogeneity may lead to biased estimation results. One additional feature regards a possible endogeneity bias. In our econometric models we assumed implicitly that the causality runs from flexible workplace and HRM practices to innovations. Again due to data limitations we were not able to employ suitable instrumental variable strategies for these dummy variables. It is left to future studies to take the endogeneity of organizational changes explicitly into account and to disclose the factors which induce establishments to change their organization of work.

A Descriptive Results

Table 17: Share of establishments with flexible workplace and HRM practices

	Before 1993	1995	1998	2000
		Germany (≤ 5 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	4.10% (n.a.)	3.49% (1.32%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	2.14% (n.a.)	0.89% (0.56%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	1.05% (n.a.)	0.75% (0.38%)
		West-Germany (≤ 5 employees)		
Flexibility	0.84% (1.17%)	6.88% (6.11%)	3.51% (2.54%)	3.96% (0.83%)
Teamwork	6.48% (0.84%)	1.51% (1.52%)	1.72% (1.08%)	1.04% (0.45%)
Responsibility	0.67% (0.67%)	1.51% (1.35%)	0.86% (0.88%)	0.90% (0.45%)
		East-Germany (≤ 5 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	4.60% (n.a.)	2.98% (1.77%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	2.51% (n.a.)	0.73% (0.66%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	1.22% (n.a.)	0.59% (0.32%)
		Germany (5-500 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	25.42% (n.a.)	22.02% (11.10%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	16.53% (n.a.)	12.36% (6.42%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	15.22% (n.a.)	10.95% (6.61%)
		West-Germany (5-500 employees)		
Flexibility	9.22% (9.22%)	29.70% (27.99%)	27.25% (19.09%)	25.79% (13.49%)
Teamwork	5.81% (5.81%)	15.79% (14.94%)	16.55% (11.60%)	14.11% (7.49%)
Responsibility	3.33% (3.33%)	11.70% (11.65%)	14.06% (10.77%)	11.71% (6.38%)
		East-Germany (5-500 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	23.97% (n.a.)	16.21% (9.30%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	16.51% (n.a.)	9.66% (5.56%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	16.14% (n.a.)	9.76% (6.80%)
		Germany (> 500 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	47.36% (n.a.)	35.01% (19.32%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	40.05% (n.a.)	29.86% (13.19%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	31.08% (n.a.)	26.35% (17.61%)
		West-Germany (> 500 employees)		
Flexibility	14.09% (14.09%)	51.68% (51.00%)	54.76% (41.95%)	40.53% (25.75%)
Teamwork	11.31% (11.31%)	38.83% (37.51%)	45.13% (29.65%)	32.70% (14.52%)
Responsibility	11.98% (11.98%)	27.90% (28.21%)	34.57% (29.73%)	28.36% (18.59%)
		East-Germany (> 500 employees)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	4.60% (n.a.)	2.98% (1.77%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	29.34% (n.a.)	21.49% (11.44%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	23.72% (n.a.)	20.92% (16.08%)

Note: The first figure in the cells reflects the share of establishments including those which have already introduced organizational changes in the past while the figures in brackets contain the share of establishments excluding those which have already introduced such an change in the last two/three years.

Table 18: Share of establishments with flexible workplace and HRM practices

	Before 1993	1995	1998	2000
		Germany (Industry)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	31.04% (n.a.)	22.61% (12.85%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	23.65% (n.a.)	16.05% (7.09%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	18.39% (n.a.)	10.55% (7.16%)
		West-Germany (Industry)		
Flexibility	9.80% (9.8%)	39.70% (38.78%)	36.37 (22.90%)	28.49% (18.06%)
Teamwork	7.47% (7.47%)	30.48% (29.10%)	28.99 (17.54%)	20.58% (8.67%)
Responsibility	12.41% (12.41%)	19.30% (18.97%)	20.58 (17.86%)	12.72% (9.35%)
		East-Germany (Industry)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	24.44% (n.a.)	14.47% (7.67%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	17.04% (n.a.)	9.78% (5.52%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	15.68% (n.a.)	7.54% (4.71%)
		Germany (Service sector)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	24.46% (n.a.)	14.86% (9.16%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	16.87% (n.a.)	8.15% (4.79%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	13.27% (n.a.)	8.74% (6.09%)
		West-Germany (Service sector)		
Flexibility	10.02% (10.02%)	28.63% (26.80%)	26.35% (18.50%)	17.40% (10.80%)
Teamwork	6.74% (6.74%)	14.18% (13.31%)	18.12% (12.78%)	9.24% (5.60%)
Responsibility	2.13% (2.13%)	12.32% (12.32%)	13.30% (12.21%)	9.47% (6.23%)
		East-Germany (Service sector)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	22.15% (n.a.)	10.88% (7.33%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	15.35% (n.a.)	6.46% (3.88%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	13.21% (n.a.)	7.61% (5.92%)
		Germany (Industry related services)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	27.76% (n.a.)	16.28% (10.77%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	19.26% (n.a.)	8.61% (5.58%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	16.43% (n.a.)	8.61% (8.12%)
		West-Germany (Industry related services)		
Flexibility	12.84% (12.84%)	34.90% (32.78%)	29.68% (18.81%)	18.44% (12.38%)
Teamwork	7.96% (7.96%)	15.55% (14.73%)	19.39% (15.07%)	9.74% (5.87%)
Responsibility	0.90% (0.9%)	15.73% (15.51%)	17.54% (17.97%)	9.94% (7.73%)
		East-Germany (Industry related services)		
Flexibility	n.a. (n.a.)	n.a. (n.a.)	25.32% (n.a.)	12.21% (8.96%)
Teamwork	n.a. (n.a.)	n.a. (n.a.)	19.10% (n.a.)	6.49% (5.25%)
Responsibility	n.a. (n.a.)	n.a. (n.a.)	15.02% (n.a.)	6.10% (8.57%)

Note: The first figure in the cells reflects the share of establishments including those which have already introduced organizational changes in the past while the figures in brackets contain the share of establishments excluding those which have already introduced such an change in the last two/three years.

B Cluster and Correlation Analysis

A major problem of every cluster analysis is to answer the question how many clusters to form.[27] Thereby a trade-off between a low variance within each cluster and a preferable low number of clusters arises. In order to detect the optimal number of clusters we first of all computed a variety of dissimilarity measures depending on the number of clusters. Figure 6 contains the root mean square standard deviation, R^2, the semi-partial R^2 and the cubic clustering criterion. The root mean square standard deviation should be as small as possible whereas the cubic clustering criterion should be maximized. Large jumps of the R^2 and the semi-partial R^2 give hints for an optimal number of clusters. Looking at figure 6 one can identify that the optimal number of clusters lies between two and three.

Figure 6: Detecting the optimal number of clusters

Having identified the optimal number of clusters we conducted a non-hierarchical clustering with two and three clusters, respectively. Since the number of observations in the third cluster was rather small, namely 2,609 establishments for $Cluster_1$, 3,325 for $Cluster_2$ and only 248 for $Cluster_3$ we repeated the cluster analysis with only two clusters using an Euclidean distance measure and the standard Ward's method. The next table contains the results of a correlation analysis for the different flexible workplace and HRM practices.

[27] For a discussion on cluster analysis see e.g. Sharma (1996).

Table 19: Pearson correlation coefficient between different flexible workplace and HRM practices

	w_1	w_2	w_3	w_5	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}	h_{12}	h_{13}	h_{14}	h_{15}
w_1	1.00	0.41	0.32	0.23	0.24	0.27	0.23	0.25	0.03	0.09	0.03	0.21	0.25	0.12	0.23	-0.01	-0.09	0.06	0.13†
w_2	0.41	1.00	0.28	0.20	0.21	0.24	0.21	0.24	0.05	0.08	0.03	0.20	0.20	0.10	0.21	-0.01	-0.10	0.06	0.12†
w_3	0.32	0.28	1.00	0.17	0.22	0.20	0.19	0.19	0.04	0.10	0.03	0.17	0.18	0.03	0.17	-0.01	-0.09	0.03	0.09†
w_4	0.23	0.20	0.17	1.00	0.24	0.24	0.16	0.24	0.04	0.12	0.03	0.24	0.25	0.13	0.22	-0.01	-0.10	0.03	0.17†
h_1	0.24	0.21	0.22	0.24	1.00	0.49	0.41	0.39	-0.03	0.18	0.01	0.49	0.22	-0.02	0.35	-0.02	-0.04	0.03	0.15†
h_2	0.27	0.24	0.20	0.24	0.49	1.00	0.42	0.41	-0.04	0.18	0.05	0.48	0.22	-0.03	0.35	-0.02	-0.07	0.03	0.14†
h_3	0.23	0.21	0.19	0.16	0.41	0.42	1.00	0.43	-0.03	0.17	0.02	0.41	0.16	-0.10	0.36	-0.02	-0.05	0.02	0.17†
h_4	0.25	0.24	0.19	0.24	0.39	0.41	0.43	1.00	0.00	0.14	0.03	0.37	0.22	0.00	0.30	-0.02	-0.09	0.03	0.16†
h_5	0.03	0.05	0.04	0.04	-0.03	-0.04	-0.03	0.00	1.00	0.04	0.03	-0.03	0.05	0.10	-0.02	0.00	-0.08	0.00	-0.03†
h_6	0.09	0.08	0.10	0.12	0.18	0.18	0.17	0.14	0.04	1.00	-0.01	0.26	0.04	-0.06	0.21	-0.01	-0.05	0.01	0.06†
h_7	0.03	0.03	0.03	0.03	0.01	0.05	0.02	0.03	0.03	-0.01	1.00	0.02	0.01	0.03	0.02†	0.00	0.06	0.00	0.01†
h_8	0.21	0.20	0.17	0.24	0.49	0.48	0.41	0.37	-0.03	0.26	0.02	1.00	0.18	-0.06	0.46	-0.03	-0.13	0.03	0.12†
h_9	0.25	0.20	0.18	0.25	0.22	0.22	0.16	0.22	0.05	0.04	0.01	0.18	1.00	0.22	0.17	-0.01	-0.10	0.05	0.13†
h_{10}	0.12	0.10	0.03	0.13	-0.02	-0.03	-0.10	0.00	0.10	-0.06	0.03	-0.06	0.22	1.00	0.01†	-0.03	-0.16	0.12	0.02†
h_{11}	0.23	0.21	0.17	0.22	0.35	0.35	0.36	0.30	-0.02	0.21	0.02†	0.46	0.17	0.01†	1.00	0.00	-0.09	0.04	0.46
h_{12}	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	0.00	-0.01	0.00	-0.03	-0.01	-0.03	0.00	1.00	-0.01	0.00	0.01†
h_{13}	-0.09	-0.10	-0.09	-0.10	-0.04	-0.07	-0.05	-0.09	-0.08	-0.05	0.06	-0.13	-0.10	-0.16	-0.09	-0.01	1.00	-0.08	-0.01†
h_{14}	0.06	0.06	0.03	0.03	0.03	0.03	0.02	0.03	0.00	0.01	0.00	0.03	0.05	0.12	0.04	0.00	-0.08	1.00	0.01†
h_{15}	0.13†	0.12†	0.09†	0.17†	0.15†	0.14†	0.17†	0.16†	-0.03†	0.06†	0.01†	0.12†	0.13†	0.02†	0.46	0.01†	-0.01†	0.01†	1.00

Notes: w_i refers to the i-th flexible workplace practice listed in table 4 whereas h_i indicates the i-th flexible HRM practice.
All correlation except those marked with a † were significant at least on a 5%-level.

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