Organizational Complementarities in the Innovation Process: An Empirical Analysis of Luxembourg Firms

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Abstract

The literature has pointed out the necessity to realize organizational innovation to support technological innovation. However, which organizational practices should be chosen, and are they compatible? Is it favorable to technological innovation to implement "business practices", "knowledge management", "workplace organization" and "external relations" at the same time? Which combinations are more effective? No answer has been given to these questions. The aim of this paper is precisely to investigate the complementarities between different organizational practices.

Firm-level data was drawn from the Community Innovation Survey (CIS 2006) carried out in 2008 in Luxembourg. The results, based on robust empirical research, provide empirical evidence in favor of the impact of complementary asset management as raising firm's innovativeness and performance, supporting previous theoretical studies of authors such as Teece (1986) or Stieglitz and Heine (2007). Implementation of new "work organization" systems has a significant and positive impact on the innovative performance. The joint realization of "workplace organization" and "external relations" raises firms' innovativeness. "Business practices" have a beneficial role on firm innovativeness only if they are simultaneously used with other organizational practices such as "knowledge management" and "external relations". The results also point out the fact that these combinations are not the same according to whether the firm is in the first step of the innovation process (i.e. being innovative), or in a latter step (i.e. performing as far as innovation is concerned). Managers should therefore be aware of the various effects and adoption of these organizational practices for technological innovation.

Keywords: complementarities, innovation, organizational innovation, performance.

1. Introduction

Many authors (Penrose, 1959; Nelson and Winter, 1982; Wernerfelt, 1984; Teece, 1988) and other theorists of the resource-based view (RBV), highlight the importance of managing different types of resources. However, the question of whether these resources are complements or substitutes has not been given many answers since the notion of complementary assets was introduced by Teece (1986). Since then, in the resource-based view of strategy and in evolutionary economics, complementary assets play a crucial role in explaining sustainable competitive advantages and innovations. However, as Stieglitz and Heine (2007, 1) point out, "despite the apparent importance of complementary assets for the understanding of corporate strategy, their creation and the associated managerial problems have been much less discussed".

This is especially true as far as innovation activities are concerned. Recently, Schmiedeberg (2008) has provided new insight on the complementarity of different innovation activities, showing that internal R&D, R&D contracting, and R&D cooperation are not always complements. Another stream of research has shown that other types of innovation (such as organizational or marketing) may lead to higher technological innovation performance. Indeed, firms are constrained to organize the innovation process efficiently by combining technological capabilities with competencies and knowledge in finance, management, organization, entrepreneurship etc. As suggested by Teece (1986, 1988) or Langlois and Robertson (1995), these often specific, tacit and inimitable competencies strongly depend on firms' capability to capture and assimilate external information, as well as to adapt to environmental changes.

Recent works have emphasized the impact of managing complementary assets on firm's innovativeness (Stieglitz and Heine, 2007). Teece (1986) view complementary assets as raising the value of a firm's technological innovations. Examples for complementary assets include marketing, organizational capabilities, regulatory knowledge, contacts with clients, etc. Some studies focus on whether complementarity assets should be integrated or not into the firm; showing that firms should try to vertically integrate complementary downstream assets (Teece, 1988; Afuah, 2001). Besides, complementary assets help innovators to successfully appropriate Schumpeterian rents as they constitute important barriers to imitation. Having access to complementary assets is also one of the objectives pursued by firms entering collaborative arrangements and networks (Teece, 1986; Mowery *et al*., 1998; Harrison *et al*., 2001).

Following Stieglitz and Heine (2007), we see assets or activities as mutually complementary if the marginal return of one activity increases the level of the other activity. This would be the case if, for instance, a firm invests in organizational innovation by introducing new knowledge management systems, leading to increased technological innovation. We are here at the heart of the traditional link between strategy and organization, changes in strategy inducing changes in organization - and vice-versa. Complementarities giving rise to synergies among the complementary activities, not taking it into account may lead to a loss in value creation and performance, because the firm fails to realize its full potential. For example, if a new product requires a new sale organization, that the firm does not undertake, the firm might be in a position not to be able to reap the benefits of its technological innovation. Milgrom and Roberts (1995) thus emphasize that the various complementary activities should be adopted together by the firm.

Several empirical studies have investigated the presence of synergistic effects that may arise from simultaneous adoption of complementary organizational practices, showing however controversial results (Ichniowski *et al.*, 1997; Cappelli and Newmark, 2001). Although the recent literature has substantially improved our understanding of complementarities, the measures of organizational practices frequently used are limited to new workplace organization or to new human resource management practices. Other forms of organizational innovation such as outsourcing, partnership, sub-contracting, training or up-skilling are not usually taken into account. Therefore, alternative organizational practices are not studied together.

The objective of this paper is to investigate the complementarity between four types of organizational practices: business practices, knowledge management, workplace organization and external relations. We are first trying to know why some firms decide to invest in organizational innovation and others do not. Second, we wonder whether synergistic effects of different organizational strategies impact performance. For this purpose, a two-step analysis is performed. The first step consists in analyzing the conditional correlation between practices. The second step directly tests the impact of simultaneous combinations of practices on the firm's innovativeness.

The article is organized as follows. The next section reviews the literature on different practices of organizational innovation and on complementarities. The third section presents the methodology used. The fourth section describes the dataset, the variables and the empirical test. The results are presented and discussed in the fifth section. Conclusive remarks and future directions of research are given in the sixth section.

2. Organizational innovation and complementarities

Theoretically, *organizational innovation* is a broad concept that encompasses strategic, structural and behavioral dimensions (Gera and Gu, 2004). The notion of organizational innovation is subject to various definitions and interpretations (Lam, 2004). Black and Lynch (2005) view organizational innovation as including components such as workforce training, work design (more decentralized and flexible allocation of labor in the firm), employee voice (allowing workers to have greater autonomy and discretion in their work) and shared rewards (incentives such as profit sharing or stock options).

Firms who are active in technological innovation (TI) usually adopt complementary organizational practices. Numerous studies have investigated the complementarity between organizational innovation and TI by highlighting the importance of technological innovation as a driver of organizational changes within the firm (Henderson and Clark, 1990; Dougherty 1992; Danneels, 2002). These studies have focused on the fact that TI usually conduces to organizational innovation. Firms introducing TI would therefore be constrained to reorganize their production, workforce, sale and distribution systems. Another research stream points out the inverse relationship by stressing the role of organizational innovation in enhancing flexibility and creativity – which, in turn, facilitates the development of TI (Ménard, 1994; Greenan *et al.,* 1993). Using a sample of firms in the fast-moving consumer goods industry in Germany, Lokshin *et al.* (2008) studied the effect of organizational competencies on firms' innovative performance, showing that firms implementing a combination of customer, organizational and technological competencies tend to introduce more innovations. Whatever the research perspective, the crucial role of organizational practices on competitive advantage and firm performance is acknowledged.

According to the OECD recommendations published in the Oslo manual (OECD/Eurostat, 2005), organizational innovation encompasses four types of practices: business practices, knowledge management systems, workplace organization and external relations. The first category of organizational innovation refers to the introduction of new business practices, which aims to organize work and procedures. Examples of this practice are supply chain management, business re-engineering, lean production, quality management.

The second category of organizational innovation refers to the introduction of knowledge management systems. The knowledge management, here including

complementary practices such as management skills, up-skilling of employees, sharing, codification and storage of knowledge is usually associated with more flexibility, adaptability, competitive advantage and better organizational performance (Prahalad and Hamel, 1990; Grant, 1996; Spicer and Sadler-Smith, 2006).

The third category of organizational innovation refers to the change to the work organization. The European Commission's 1997 Green Paper sees it a key priority for higher competitiveness, based on high skill, trust and quality. According to OECD (2001), new work practices are related to decentralize decision-making, job rotation, team work and shared rewards. Implementing new work organization could result in substantial improvements in organizational flexibility which in turn leads to improved firm efficiency and performance.

The fourth organizational practice refers to relations with other firms or public institutions, through alliances, partnerships, outsourcing or sub-contracting. The growing role of networking in firms' innovative capabilities is closely linked to the context of the emerging knowledge-based global economy. Because of the tacit and non transferable character of knowledge and of the evolutionary and continual character of the learning process, innovative firms should concentrate on their specific capabilities while involving in cooperative arrangements in order to develop new competencies and extensions of the firm's know-how to new applications. Firms should moreover be encouraged to engage in external relations in order to access partners' complementary or synergistic competencies and capitalize "*incoming spillovers*" (Kogut, 1988, Kogut and Zander, 1993; Cassiman and Veugelers, 2002), to reduce the duplication of R&D efforts as well as risks and costs associated to innovation projects (Jacquemin, 1988; Sakakibara, 1997), to benefit from scale economies (Kogut, 1988).

"If and to what extent the complementarities assumed by economic theory exist has been discussed in the literature since the nineties. But empirical research has not come to a clear conclusion yet: a large part of the literature concentrates on the relation of internal and external R&D as input factors to innovation" (Schmiedeberg, 2008, 1493). In particular the influence of internal R&D on R&D cooperation has been investigated at length. Some authors refer to complementarity when explaining the link between internal and external R&D; however, the positive correlation between internal and external R&D does not necessarily imply complementarity of these activities. The same confusion exists in the field of organizational innovation while some authors (Schmidt and Rammer, 2007) speak of complementarity; "real" tests of complementarity (in line with Milgrom and Roberts, 1995) have been scarce. And, to analyze the relationship in detail, more elaborate methods are used by a number of researchers to test complementarities.

3. Approaches for testing complementarities

The concept of complementarity refers to the existence of systems' effects and synergies of alternative activities, and has been widely used to study innovation processes. A set of organizational practices are complements if their simultaneous implementation pays off more than the isolated adoption of each of them. In order to test for complementarities, different approaches exist in the literature (see Athey and Stern, 1998). The first one is based on the analysis of the correlation between various organizational practices (also called 'adoption' analysis), conditional on a common set of exogenous variables. The second one consists in testing the contribution of different combinations of practices directly on the firm innovative performance (also called "performance' analysis).

3.1. The indirect approach: correlation or adoption analysis

The intuition is based on the idea that complementarities create a force in favor of positive correlation between two activities. If alternative activities are complementary, then we would expect that rationally behaving firms exploit this opportunity, investing in these activities at the same time and in the same direction. However, Athey and Stern (1998) note that two activities could be correlated without being complements or/and that the potential correlation may be hidden by the influence of a common set of exogenous factors. In order to take this problem into account, conditional correlations are calculated based on the residuals of reduced form regressions of the activities on a set of common observable variables. The existence of positive (negative) conditional correlation coefficients may imply a complementarity (substitutability) between two activities.

This approach has been by far the most simple and popular among empirical researchers for testing the complementarity (Arora and Gambardella, 1990; Ichniowski *et al.*, 1997; Galia and Legros, 2004). The advantage of this approach is to provide some supportive evidence of complementarity if activities are adopted simultaneously without requiring any performance measure. Despite this advantage and its relative simple use, it does not provide a sufficient condition to conclude that an eventual relation of complementarity exists between two activities. It is complementarity which implies, under some conditions, positive correlation – but the reverse is not always true (Catozzella and Vivarelli, 2007). Another approach must be carried out in order to get more fully supported conclusions.

3.2 The direct approach: performance analysis

This approach is based directly on the objective function of the firm. The main idea is that the simultaneous implementation of different activities should prove to be more valuable than implementing each of them separately. The test of complementarity is thus performed by regressing a measure of firm performance on a set of interaction terms between considered activities, interpreted as parameters of complementarities. Comparing the impacts of alternative combinations of activities stemming from this estimation allow detecting the complementarity between these activities. One can obtain a certain supportive evidence of complementarity (substitutability) when significant and positive (negative) coefficients of the interaction terms are observed.

Formally, this approach can be traced back to the theory of supermodularity (Topkis, 1998; Milgrom and Roberts, 1995). The intuition is that whenever activities are complementary, then the objective function is supermodular. Applying this approach, Mohnen and Röller (2005) directly estimated the innovation function and investigate whether policy decisions (i.e. obstacles to innovation that are affected by policies) are complementary. Lokshin *et al.* (2004) studied the complementarity between product, process and organizational innovations and their impact on labour productivity. Ichniowski *et al.* (1997) also used this approach for testing the complementarity between different human resource management practices. They found, on a sample of 36 homogeneous steel production lines, that using a set of innovative work practices such as teams, flexible job assignments or training leads to higher output level and product quality. This approach is also used by authors who investigate complementary innovation activities (in-house R&D, external technology sourcing, etc.) and their impact on firm performance (Cassiman and Veugelers, 2006; Schmiedeberg, 2008).

4. Data and methodology

4.1 Dataset

The empirical analysis is based on firm-level data drawn from the Luxembourgish Community Innovation Survey (CIS2006) carried out in 2008 by CEPS/INSTEAD[1] in collaboration with STATEC[2]. The objective of this survey is to collect data on firms' innovation behavior, over the three-year period from 2004 to 2006, according to the OECD recommendations published in the Oslo manual (OECD/Eurostat, 2005). It provides a set of firms' general information (sector of activities, group belonging, number of employees, sales, geographic market), information about technological and non-technological innovation as well as perceptions of factors hampering innovation activities or subjective evaluation of the effects of innovation. The dataset also comprises information about sources of information and various types of R&D cooperation for innovation activities. For the purpose of this paper, we used a sub-sample of firms with a least 10 employees in the manufacturing and the service sectors. We thus obtained a sample of 568 representative firms.

4.2 Variables

Two dependent variables are used. The first one, *innovative performance*, is measured as the percentage of total turnover from product innovations that are new to the firm (Mairesse and Mohnen, 2002; Mohnen and Röller, 2005; Cassiman and Veugelers, 2006). In addition, we have also information on whether a firm innovates. Thus, the second dependent variable is the *propensity to innovate* (cf. Appendix A for definitions of all variables).

The CIS provides data on organizational innovation that firms implemented during the period 2004-2006. Four practices of organizational innovation are categorized in the survey: (1) new business practices for organizing work and procedures, (2) new knowledge management systems, (3) new methods of workplace organization and (4) new methods of organizing external relations (see Appendix A). Four dummy variables are then constructed for each of these practices. The objective of the paper is to investigate the complementarity between these organizational practices.

[1] International Network for Studies in Technology, Environment, Alternatives, Development

[2] Central Service of Statistics and Economic Studies

We also included, as many studies have focused on them, four innovation activities performed by firms during the three years 2004 to 2006: (1) in-house R&D, (2) extramural R&D, (3) technological acquisition and (4) knowledge acquisition.

In the questionnaire, firms are asked to evaluate the importance of obstacles to innovation. We constructed three dummy variables according to the obstacles' importance: (1) *financial obstacles* taking the value 1 if the scores of importance of lack of funds or/and high costs of innovation is crucial; (2) *knowledge obstacles* taking the value 1 if the scores of importance of lack of qualified personnel or/and lack of information on technology or on market or/and difficulty in finding cooperation partners is crucial; (3) *market obstacles* taking the value 1 if the scores of importance of uncertainty of products demand or/and dominance of established firms is crucial.

The data also allows determining different motivations for firms' innovation efforts. In the questionnaire, firms rated the importance of products or processes innovation effects on a Likert scale (0 to 3). Similarly to Belderbos *et al.* (2004), we generate the cost-push variable by summing the scores of cost-related objectives such as improved flexibility, increased capacity of production, reduced labor costs, materials or energy. Then, we rescaled the total score to a number between 0 and 1. The demand-pull variable is generated in a similar way, summing scores of demand-related objectives such as increased range of products, increased market share or improved quality of products. The sum is then rescaled between 0 and 1.

Firms were also asked to rate the importance of information sources on a Likert scale (0 to 3). We constructed five dummy variables of information sources taking the value 1 if the score is crucial and 0 otherwise: (1) *public sources* as a composite measure of information sources from universities or other higher education institutions, government or public research institutes; (2) *private sources* from consultants, commercial labs or private R&D institutes; (3) *market sources* from suppliers, clients or customers, competitors or other firms in the same sector.

Firm size is measured by the natural logarithm of the number of employees. We also introduced a dummy variable of group belonging, taking the value 1 if the firm is independent (reference), 2 if firm belongs to a domestic group, 3 if it is part of a European group and 4 if it is part of an extra-European group. Eight sectors of activities are included, according to the two-digit NACE classification: (1) High and medium high-tech manufacturing industry; (2) Medium low-tech manufacturing industry; (3) Low-tech manufacturing industry; (4) Transport and communication; (5) Financial intermediation; (6) Computer activities; (7) R&D

– Engineering activities and consultancy, Technical testing and analysis and (8) Wholesale trade (reference).

4.3 Empirical tests

This paper aiming at evaluating complementary relations between different organizational practices, we used a two step analysis. First, the factors determining the introduction of different practices of organizational innovation are explored, conditional to a set of firm's observable characteristics. We thus perform a multivariate Probit model which includes four equations estimating the four organizational practices. This method allows us to investigate the correlation between organizational practices conditional on a set of explanatory variables.

Second, we use the direct approach (or performance approach) for testing the complementarity by estimating the 'innovation function'; alternative combinations of organizational practices are included as explanatory variables. The performance approach focuses directly on the relation between innovative performance and different practices of organizational innovation. This is done to compare the impact of alternative combinations of practices on firm performance. Similarly to Mohnen and Röller (2005), we estimate the function which takes the following form:

$$I_i = \sum_{n=0}^{15} S_n \gamma_n + X_i' \alpha + \varepsilon_i \qquad (1)$$

where I_i is innovative performance for firm *i*, measured as the share in sales of innovative products (PERFOR). According to the performance approach, a set of state dummy variables S_n is inserted in the model. As four organizational practices are considered, we obtain16 dummy variables s0_0_0_0, s0_0_0_1, …,s1_1_1_1. X_i represents the set of explanatory variables, including controls for firm-level heterogeneity such as firm size, sectors of activities, foreign ownership and also a set of variables which have previously shown to be relevant determinants of innovative performance at the firm level, such as the intensity of internal and external R&D, obstacles to innovation.

Since we draw on the sub-sample of innovative firms from the dataset, sample selection bias arises. Heckman two-step estimation (1979) is thus particularly adapted for

treating this problem as our purpose is to estimate, on the subset of those 259 firms who declared themselves innovative out of a total of 551, their innovative performance. Heckman's estimation provides a way of estimating treatment effects when the treated sample (our 259 innovative firms) is self-selected (as it is the case through their responses to the questionnaire) and so the effects of the treatment are confounded with the population that chose it because they expected it would help. According to this method, before estimating the model for innovative performance for the sub-sample of innovative firms (equation 1), we estimate a Probit equation for the probability to innovate for the full sample of firms, innovative or not. The function of probability to innovate is written as follows:

$$Pro_i = \sum_{n=0}^{15} S_n \delta_n + W_i' \beta + v_i \qquad (2)$$

where Pro_i is the latent variable corresponding to the probability to innovate (PROD_INN). Innovating firms have positive values for Pro_i and non-innovating firms have negative values. W_i is the set of control variables, including firm size, sectors of activities, foreign ownership and obstacles to innovation.

Besides the correction of the selection bias, this method also allows to assess the impact of organization and marketing innovations on the probability of firms to become innovative. Recall that the probability to innovate and the financial success of innovative products measured by the share of sales represent two separate phases of the innovation process. Therefore, one can expect differences in the effects of the introduction of new or improved organizational or marketing innovations according to these two different phases.

Afterwards, we perform supermodularity and submodularity tests for respectively complementarity and substituability in organizational practices based on consistent estimates of the γ_n (Equation 1) as in Mohnen and Röller (2005). The hypotheses that pair 1-2 is strictly supermodular are:

$H_0 : h_0 < 0$ and $h_1 < 0$ and $h_2 < 0$ and $h_3 < 0$ (null hypothesis)
$H_1 : \quad h_0 \geq 0$ or $h_1 \geq 0$ or $h_2 \geq 0$ and $h_3 \geq 0$ (alternative hypothesis)

where $h_s = - \gamma_{0+s} + \gamma_{4+s} + \gamma_{8+s} - \gamma_{12+s}$, $s=0,1,2,3$. The test is based on the Wald test for inequalities of Kodde and Palm (1986). As variable *s0_1_0_1* is excluded in our regressions because of collinearity, we therefore include in our tests the constraint $\gamma_5 = 0$. Tests for other pairs are defined analogously.

Similarly, testing the strict submodularity for the pair 1-2 concerns the following hypotheses:

$H_0 : h_0 > 0$ and $h_1 > 0$ and $h_2 > 0$ and $h_3 > 0$
$H_1 : h_0 \leq 0$ or $h_1 \leq 0$ or $h_2 \leq 0$ and $h_3 \leq 0$

5. Results and discussion

The results of the multivariate Probit model for the complete sample of 568 observations are presented in Table 2. From this estimation, the conditional pair-wise correlation among the residuals of the four practices are computed (Table 1). Note that the correlation coefficients, after controlling for firm-specific effects, are positive and highly significant. These results are quite similar for unconditional correlations between the four practices (see Appendix B). The correlation coefficient is particularly high between "business practices" and "knowledge management" or between "workplace organization" and "knowledge management". Overall, these results provide some suggestive support of the interdependence between the decisions to adopt certain organizational practices, which may be influenced by the complementarity in the practices of organizational innovation, but also by omitted firm-specific factors affecting all practices (Belderbos *et al.*, 2004).

Table 1 – Conditional correlation between organizational practices

	Business practices	Knowledge management	Workplace organization	External relations
Business practices	1.000			
Knowledge management	0.703***	1.000		
Workplace organization	0.607***	0.711***	1.000	
External relations	0.484***	0.537***	0.618***	1.000

Looking at the determinants of the decision to invest in different organizational practices, the results show a significant and positive effect of in-house R&D investment on the decision to adopt "business practices" and "knowledge management", while no such evidence is found for "workplace organization" and "external relations" (Table 2). Significant and positive

coefficients are also found regarding the acquisition of advanced machinery, equipment and software, which affects the four practices. We expect that firms investing in technological acquisition, producing new or significant improved products and processes, should be constrained to reorganize their workforce, to implement new work organization and management systems - in order to adapt to new production instruments and new work environment.

Table 2 – Results of multivariate Probit model for organizational practices

	Business practices	Knowledge management	Workplace organization	External relations
In-house R&D	0.325 (0.045)**	0.404 (0.011)**	0.046 (0.766)	-0.053 (0.754)
Extramural R&D	0.160 (0.346)	0.041 (0.801)	0.108 (0.505)	0.305 (0.081)*
Technological acquisition	0.569 (0.000)***	0.286 (0.042)**	0.539 (0.000)***	0.345 (0.026)**
Knowledge acquisition	0.132 (0.568)	0.187 (0.469)	0.014 (0.925)	0.003 (0.845)
Public sources	0.102 (0.740)	0.016 (0.956)	0.084 (0.770)	-0.352 (0.257)
Private sources	0.022 (0.933)	0.603 (0.032)**	0.261 (0.347)	0.011 (0.964)
Market sources	0.074 (0.611)	0.159 (0.262)	0.098 (0.482)	0.203 (0.172)
Financial obstacles	0.169 (0.293)	0.081 (0.603)	0.062 (0.681)	0.141 (0.399)
Knowledge obstacles	0.248 (0.101)*	0.341 (0.019)**	0.450 (0.002)***	0.228 (0.140)
Market obstacles	-0.401	-0.260 (0.083)*	-0.344 (0.018)**	-0.017 (0.909)
Competitors actions	0.124 (0.061)*	0.117 (0.081)*	0.105 (0.102)*	0.097 (0.179)
Market position	0.004 (0.938)	0.134 (0.032)**	0.023 (0.655)	-0.221
Technological changes	-0.029 (0.614)	-0.080 (0.171)	-0.091 (0.103)*	-0.120 (0.052)**
Size	0.145 (0.009)***	0.052 (0.328)	0.106 (0.045)**	0.116 (0.035)**
Domestic groups	0.204 (0.232)	0.354 (0.037)**	-0.078 (0.641)	0.202 (0.247)
European groups	0.014 (0.925)	0.059 (0.701)	0.076 (0.606)	0.000 (0.999)
Extra Europe groups	0.003 (0.988)	0.164 (0.449)	0.149 (0.481)	-0.413 (0.091)*
Sector dummies included	yes	yes	yes	yes
Constant	-1.226	-1.200	-0.959	-1.179
Observation	568			
Log likelihood	-1056.13			
Wald $\chi^2(92)$	228.49***			

Notes: *, ** and *** denote significance at the level of 10%, 5% and 1%. P-values are in parentheses.

It is interesting to note that the perception of knowledge-related obstacles to innovation is positively associated with the introduction of organizational innovation. By contrast, the perception of market-related obstacles to innovation has significant and negative impact on the adoption of organizational practices. In other words, when the market is dominated by well established firms and by the uncertainty about the demand for innovative goods and services, firms tend to focus less often on “business practices”, “knowledge management” or “workplace organization”.

Surprisingly, information sources, often considered as crucial for innovation, are not associated with the adoption of neither “workplace organization”, “business practices” nor “external relations”. This is counter-intuitive and in contrast with recent trends in the

literature which emphasize that firms actively develop organizational strategies to benefit from "*incoming spillovers*" (Kogut, 1988; Kogut and Zander, 1993; Cassiman and Veugelers, 2002).

We find however that firms which consider private organisms (consultants, commercial laboratories or private R&D institutes) as crucial information sources for innovation tend to more introduce new knowledge management systems. This is not surprising considering that one of the main objectives of knowledge management systems is to allow firms' employees to better use and exchange information, knowledge and skills, as well as to collect and appropriate information from outside.

Another interesting result is that the competition context on the firms' main market is likely to motive firms to introduce organizational innovation. We find that, on the market where competitors' actions are difficult to forecast, firms seem more likely to adopt "business practices", "knowledge management" and "workplace organization". This result is in line with the findings of Nickell *et al.* (2001) or Pil and MacDuffie (1996) indicating that firms are motivated to invest more in reorganization when the real output price or performance is declining - which can be due to increased competition both domestically and internationally. We also find that the threat of the arrival of new competitors on the market is associated with the adoption of new knowledge management systems, while this type of market competition discourage firms to engage in "external relations".

Among the set of control variables, the activity sector is, in general, not significant. This is in line with recent research in strategic management: the firm's organizational strategy does not depend on the sector-level but rather on firm-specific characteristics which, in turn, influence the incentives and ability to innovate. Generally speaking, we find few evidence of the impact of ownership on "business practices" and "workplace organization". By contrast, firms belonging to a domestic group have a higher probability to introduce "knowledge management" systems compared to non-group belonging firms. Firm size is an important determinant for the introduction of "business practices", "workplace organization" and "external relations". Firms with a higher fraction of production workers and larger production scale are more likely to adopt some specific types of organizational innovation. By contrast, firm size is not important in explaining the implementation of "knowledge management".

The first step of our study, which is based on the adoption approach, provided some suggestive evidences of complementarity between the four considered organizational practices. In order to further investigate this complementarity, let us turn now to the second

step that consists on directly estimating the performance function of the firm. The estimation results of the generalized Tobit model are reported in Table 3.

Table 3 – Results of the generalized Tobit model

	Propensity to innovate	**Innovative performance**
R&D intensity	37.261 (0.000)***	0.214 (0.000)***
Financial obstacles	0.329 (0.087)*	0.016 (0.379)
Knowledge obstacles	0.077 (0.657)	-0.033 (0.054)*
Market obstacles	0.214 (0.205)	0.039 (0.024)**
Size	0.242 (0.000)***	-0.011 (0.082)*
Luxembourg groups	0.394 (0.037)**	-0.002 (0.911)
European groups	0.427 (0.011)**	-0.014 (0.459)
Extra-Europe groups	0.812 (0.002)***	-0.005 (0.830)
Himedhitech	0.469 (0.068)*	-0.001 (0.967)
Metech	-0.300 (0.207)	0.034 (0.206)
Lowtech	-0.329 (0.185)	0.011 (0.714)
Transport	-0.719 (0.002)***	0.024 (0.449)
Finan	0.237 (0.341)	0.043 (0.090)*
Comp	-0.390 (0.190)	0.009 (0.753)
Rd	-0.021 (0.941)	-0.021 (0.489)
s0_0_0_0	-0.686 (0.001)***	-0.042 (0.065)*
s0_0_0_1	0.586 (0.340)	-0.067 (0.156)
s0_0_1_0	-0.527 (0.159)	0.082 (0.025)**
s0_0_1_1	-0.360 (0.389)	-0.007 (0.886)
s0_1_0_0	0.022 (0.966)	0.060 (0.290)
s0_1_1_0	0.967 (0.055)*	-0.069 (0.058)*
s0_1_1_1	-1.966 (0.075)*	-0.125 (0.257)
S1_0_0_0	-0.230 (0.470)	-0.026 (0.382)
S1_0_0_1	-0.945 (0.145)	-0.017 (0.782)
S1_0_1_0	-0.300 (0.358)	-0.013 (0.698)
S1_0_1_1	0.497 (0.242)	-0.037 (0.336)
S1_1_0_0	0.320 (0.396)	-0.016 (0.621)
S1_1_0_1	0.821 (0.139)	-0.065 (0.191)
S1_1_1_0	0.269 (0.314)	-0.025 (0.267)
S1_1_1_1	-1.149 (0.001)***	0.150 (0.003)***

Notes: *, ** and *** denote significance at the level of 10%, 5% and 1%. P-values are in parentheses.

The inverse Mills' ratio included in the model for correcting potential sample correction bias is significant. This might indicate that estimation results for innovative innovation variable are influenced by the selectivity issue.

We find out that propensity to innovate and the innovative performance depend strongly on the R&D intensity. This is in line with previous empirical findings indicating the crucial role of own R&D expenditures for innovation processes as they condition knowledge creation as well as firms' capacity to absorb external knowledge (Grilliches and Mairesse, 1984; Crépon *et al*., 1998). Regarding the obstacles to innovation, the lack of funds or finance has a positive impact on the probability to innovate. Similarly, markets factors such as uncertain demand positively affect the innovative performance. This means that firms tend to

innovate more and obtain higher financial returns when obstacles are strongly perceived (Mohnen and Röller, 2005).

Firm size affects the propensity to innovate positively and the innovative performance negatively. Lynch and Black (1998) find that smaller firms are much less likely to provide organizational programs than larger firms. Foreign ownership matters for capacity of firms to innovate, while not for commercial success of innovation.

Results show that almost all organizational practices, when separately adopted, do not have any significant impact on the propensity to innovate and on the innovative performance. Hence, implementing "knowledge management" has any effect on the innovation process. This result is not in line with the existing literature highlighting that knowledge management, including practices such as management skills, up-skilling of employees, sharing, codification and storage of knowledge is usually associated with more flexibility, adaptability, competitive advantage and better organizational performance (Prahalad and Hamel 1990; Grant 1996; Spicer and Sadler-Smith 2006). For instance, using a sample of manufacturing firms surveyed in the third French CIS, Kremp and Mairesse (2004) found that firms having knowledge management policies are likely to innovate more extensively and to have higher productivity performance. Uhlaner *et al.* (2007) showed, for a panel of Dutch firms, that firms implementing knowledge management grow more quickly than the others.

By contrast, performing "workplace organization" significantly raises innovative performance. This is consistent with the findings of Ichniowski *et al.* (1997) and Coutrot (2000) finding out that, using a set of innovative work practices such as teams, flexible job assignments or training, leads to higher output level and product quality.

It is interesting to observe that the estimation results suggest a relation of complementarity between "knowledge management" and "work organization" for the propensity to innovate while substitutability for the innovative performance.

Results of supermodularity and submodularity tests are provided in Table 4. Similarly to Mohnen and Röller (2005), we again adopt the 10% significance level for interpreting the results. The lower and upper bounds at the 10% level, provided by Kodde and Palm (1986), are 3.808 (degrees of freedom = 2) and 8.574 (df = 5) respectively. The null hypothesis H_0 is rejected if the test statistic is higher than the upper bound. H_0 is accepted if the test statistic is lower than the lower bound. The test is inconclusive for values in between the two bounds.

The test results show that most of pair-wise combinations of practices (pairs 1-2, 1-4, 2-4, and 3-4) are supermodular[3] for the innovative performance (Table 4). Indeed, as indicated by the supermodularity tests, the null hypothesis of supermodularity is accepted for pairs 1-2, 1-4, 2-4, 3-4, while rejected for pair 2-3, and inconclusive for pair 1-3. Moreover, the submodularity test rejects the submodularity for the pair 1-2 while it is inconclusive for all remaining pairs. For the propensity to innovate, these tests show that pairs 1-2 and 1-3 are supermodular, and that pairs 1-4, 2-3, 2-4, and 3-4 are submodular.

Table 4 : Supermodularity and submodularity tests

	Wald test	pair 1-2	pair 1-3	pair 1-4	pair 2-3	pair 2-4	pair 3-4
Innovative performance	supermodularity	3.397 A	4.975 N	0 A	14.653 R	0.663 A	0.902 A
	submodularity	9.639 R	8.063 N	4.407 N	4.091 N	5.999 N	6.923 N
Propensity to innovate	supermodularity	2.044 A	1.809 A	4.927 N	11.283 R	16.901 R	13.629 R
	submodularity	5.164 N	5.645 N	2.763 A	1.070 A	1.727 A	3.396 A

Notes : ^{A} *: the null hypothesis* H_0 *is accepted,* ^{R} *:* H_0 *is rejected,* ^{N} *: no conclusion*.

Overall, the test results strongly point out the fact that the effects of the pair-wise combination of these two practices might be not the same according to the phases of the innovation process.

6. Conclusion

The objective of this paper was twofold. First, we tried to understand what factors influence the firm's decision to implement organizational innovation. Second, we wondered whether alternatives organizational strategies are complements or substitutes. A two-step analysis was performed. The first one consisted in analyzing the conditional correlation between practices. The second one directly tested the impact of simultaneous combinations of practices on the firm's innovativeness, measured through the probability to be an innovator and the share in sales stemming from innovative products. Two phases of the innovation process were thus investigated: the decision to innovate or not, and the innovative performance, conditional that a firm does any innovation at all. The empirical study was based on the firm-level dataset drawn from the Luxembourgish Community Innovation Survey (CIS2006).

3 We note that pair i-j is supermodular (submodular) by meaning that i and j are supermodular (submodular).

Regarding the factors that determine the implementation of innovation organizational, we find that innovation activities such as in-house R&D investment influences the decision to adopt “business practices” and “knowledge management”, while no such evidence is found for “workplace organization” and “external relations”. Significant and positive coefficients are also found regarding the acquisition of advanced machinery, equipment and software, which affects the four practices. The perception of market-related obstacles to innovation has significant and negative impact on the adoption of organizational practices. We also find that firms which consider private organisms (i.e. consultants, commercial laboratories or private R&D institutes) as crucial information sources for innovation are more to introduce new knowledge management systems. Another interesting result is that the competition context on the firms’ main market is likely to motive firms to introduce organizational innovation. Firms that are threatened by the arrival of new competitors on the market are likely to adopt more new knowledge management systems.

Looking at the results about the complementarity, the results from the two approaches used are quite different. Thus, all pair-wise combinations of organizational practices are correlated, even when exogenous variables are controlled. Through the performance approach, where two organizational practices are considered as complements as these innovative strategies are mutually reinforcing each other - as increasing the level of any of them increases the marginal profitability of the other (Milgrom and Roberts, 1995), less significant pair-wise combinations are significant. Indeed, other underlying factors (unobserved) may cause the correlation instead of complementarity.

Overall, our study shows that, today, firms cannot only count on R&D investments to support their innovative capacity and competitiveness. Internal competencies and organizational innovation should be taken into account, specifically as they tend to be highly complementary. The results, based on robust empirical research, provide empirical evidence in favor of the impact of complementary asset management as raising firm’s innovativeness and performance, supporting previous theoretical studies of authors such as Teece (1986) or Stieglitz and Heine (2007). We show which type of organizational practices reinforce technological innovation. Some practices should be adopted simultaneously for an optimal effect, while others are productive on their own. Firms should therefore be aware of their use of organizational practices in order to combine them adequately to enhance, not only their propensity to innovate, but also their innovative performance. The results also point the fact that these combinations are not the same according to whether the firm is in the first step of the innovation process (i.e. being innovative), or in a latter step (i.e. performing as far as

innovation is concerned). Managers should therefore be aware of the various effects and adoption of these organizational practices for technological innovation.

References

Afuah, A. "Dynamic boundaries of the firm: are firms better off being vertically integrated in the face of technological change?", *Academy of Management Review*, 44, 2001, pp 1211–1228.

Armbruster, H., Bikfalvib, A., Kinkela, S., Lay, G. "Organizational innovation: The challenge of measuring non-technical innovation in large-scale surveys", *Technovation* 28, 2008, pp. 644–657.

Arora A., and Gambardella, A. "Complementarity and external linkages: the strategies of the large firms in biotechnology", *Journal of Industrial Economics*, 38:4, 1990, pp. 362-379.

Askenazy, P. "Le développement des pratiques 'flexibles' de travail," in *Nouvelle Economie, Conseil d'Analyse Economique*, D. Cohen, and M. Debonneuil (eds.), 2000, La Documentation Française, Paris, pp. 127-148.

Athey, S., and Stern, S. *An empirical framework for testing theories about complementarity in organizational design*, NBER Working Paper, 1998.

Belderbos, R., Carree, M., and Lokshin, B. "Cooperative R&D and firm performance", *Research Policy*, 33:10, 2004, pp. 1477-1492.

Black, S.E., and Lynch, L.M. "Measuring Organizational Capital in the New Economy", in *Measuring Capital in the New Economy*, C. Carol, J. Haltiwanger and D. Sichel (eds.), 2005, University of Chicago Press.

Cappelli, P., and Newmark, D. "Do high-performance work practices improve establishment-level outcomes?" *Industrial & Labor Relations Review*, 54, 2001, pp.737-775.

Cassiman B., and Veugelers R. "R&D Co-operation and Spillovers: some empirical evidence from Belgium", *American Economic Review*, 92:4, 2002, 1169-1184.

Cassiman, B., and Veugelers, R. "In Search of Complementarity in Innovation Strategy: Internal R&D, Cooperation in R&D and external Technology Acquisition", *Management Science*, 52:1, 2006, pp 68–82.

Catozzella, A., and Vivarelli, M. *Beyond the knowledge production function : the role of R&D in a multi-faceted innovation process*, Jena Economic Research Papers in Economics, 2007, 007-087.

Coutrot, T. "Relations sociales et performances économiques, une première analyse empirique du cas français", *Travail et Emploi*, 66 :1, 1996.

Crépon, B., Duguet, M., and Mairesse, J. “Research and Development, Innovation and Productivity: An Econometric Analysis at the Firm Level”, *Economics of Innovation and New Technology*, 7:2, 1998 pp 115-158.

Dougherty, D. “A Practice-Centered Model of Organizational Renewal through Product Innovation”, *Strategic Management Journal*, 23, 1992, pp 77–92.

European Commission’s Green Paper, 1997, http://europa.eu.int/comm/employment_social/

Galia, F. and Legros, D. “Complementarities between obstacles to Innovation: Evidence from France”, *Research Policy*, 33, 2004, pp. 1185-1199.

Gera, S., and Gu, W. “The Effects of Organizational Innovation and Information and Communications Technology on Firm Performance”, *International Productivity Monitor*, 9, 2004, pp 37–51.

Grant, R.M. “Toward a Knowledge-base Theory of the Firm”, *Strategic Management Journal*, 17, 1996, pp 109–122.

Greenan, N., Guellec, D., Broussaudier, G., and Miotti, L. *Innovation Organisationnelle, Dynamique Technologique et Performance des Entreprises*, INSEE Working Paper, No. G 9304, 1993.

Grilliches, Z., and Mairesse, J. “Productivity and R&D at the Firm Level”, in R&D, *Patents and Productivity*. Z. Grilliches (eds.), 1984, Chicago Press.

Harrison, J.S., Hitt, M.A., Hoskisson, R.E. and Ireland, D.R. “Resource complementarity in business combinations: extending the logic to organizational alliances”, *Journal of Management*, 27, 2001, pp 679–690.

Heckman, J. “Sample selection bias as a specification error”, *Econometrica*, 47, 1979, pp 153–161.

Henderson, R., and Clark, K. “Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms”, *Administrative Science Quarterly*, 35, 1990, pp 9-30.

Ichniowski, C., and Shaw, K. “Beyond incentive pay: insiders’ estimates of the value of complementary human resource management practice”, *The Journal of Economic Perspective*, 17:1, 2003, pp. 155-178.

Ichniowski, C., Shaw, K., and Prennushi, G. “The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines”, *American Economic Review*, 87:3, 1997, pp. 291-313.

Jacquemin, A. “Cooperative Agreements in R&D and Europe Antitrust Policy”, *European Economic Review*, 32, 1988, pp 551-560.

Kodde, D.A., and Palm, F.C. “Wald criteria for jointly testing equality and inequality restrictions”, Econometrica, 54, 1986, pp. 1243-1248.

Kogut, B. “Joint ventures: theoretical and empirical perspectives”, *Strategic Management Journal*, 9, 1988, pp. 319–332.

Kogut, B., and Zander, U. "Knowledge of the Firm and the Evolutionary Theory of the Multinational Corporation", *Journal of International Business Studies*, 24:4, 1993, pp. 625-645.

Kremp, E., and Mairesse, J. *Knowledge Management, Innovation and Productivity: a firm level exploration based on French Manufacturing data*, NBER Working Paper, 2004, No. 10237.

Langrois, R. and Robertson, P. *Firms, Markets and Economic Change. A Dynamic Theory of Business Institutions*, Routledge, 1995.

Lokshin, B., Belderbos, R., and Carree, M. Testing for complementarity and substitutability in Lokshin, B., van Gils, A., and Bauer, E. Crafting *Firm Competencies to Improve Innovative Performance*, UNU-MERIT Working Paper, 2008.

Lynch, L.M., and Black, E. "Beyond the Incidence of Training: Evidence from a National Employers' Survey", *Industrial and Labor Relations Review*, October, pp. 64-81.

Mairesse, J., and Mohnen, P. "Accounting for Innovation and Measuring Innovativeness: an Illustrative Framework and an Application," *The Economics of Technology and Innovation*, 92:2, 2002, pp.226-230.

Ménard, C. "La Nature de l'Innovation Organisationnelle", *Revue d'Economie Industrielle*, 1994, pp. 173-192.

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

Mohnen, P., and Röller, L. "Complementarities in innovation policy", *European Economic Review*, 49, 2005, pp. 1431-1450.

Mowery, D.C., and Oxley, J.E., and Silverman, B.S. "Technological overlap and interfirm cooperation: implications for the resource-based view of the firm", *Research Policy*, 27:5, 1998, pp. 507-523.

Nelson, R.R., and Winter, S.G. *An Evolutionary Theory of Economic Change*, Bellknap Cambridge Mass, 1982.

Nickell, S, and Daphne, N., and Patterson, M. "Does doing badly encourage management innovation?", *Oxford Bulletin of Economics and Statistics*, 63, 2001.

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

Pil, F., and MacDuffie, J.P. "The Adoption of high Involvement Work Practices," *Industrial Relations*, 35:3, 1996, pp. 423-455.

Prahalad, C.K., and Hamel, G. "The Core Competence of the Corporation", *Harvard Business Review*, 68:3, 1990, pp 79–91.

Sakakibara, M. "Heterogeneity of firm capabilities and co-operative research and development: an empirical examination of motives", *Strategic Management Journal*, 18:6, 1997, pp 143-16.

Schmiedeberg, C. "Complementarities of Innovation Activities: An Empirical Analysis of the German Manufacturing Sector," *Research Policy*, 37, 2008, pp. 1492-1503.

Schmidt, T., Rammer, C. 2007. Non-technological and Technological Innovation: Strange Bedfellows? Working Paper No. 07-052, ZEW, ftp://ftp.zew.de/pub/zew-docs/dp/dp07052.pdf

Spicer, D.P., and Sadler-Smith, E. "Organizational Learning in Smaller Manufacturing Firms", *International Small Business Journal*, 24:2, 2006, pp 133–158.

Stieglitz, N., and Heine, K. “Innovations and the role of complementarities in a strategic theory of the firm”, *Strategic Management Journal*, 28, 2007, pp 1–15.

Teece, D.J. “Profiting from technological innovation”, *Research Policy*, 15, 1986, pp 285–305.

Teece, D.J. “Technical change and the nature of the firm”, in *Technical Change and Economic Theory*, G. Dosi, C. Freeman, R. Nelson and L. Soete (eds.), Pinter: New York, 1988, pp 256–281.

Topkis, D.M. Supermodularity and Complementarity, Princeton, NJ, 1998.

Uhlaner, L., van Stel, A., Meijaard, J., and Folkeringa, M. The Relationship between Knowledge Management, Innovation and Firm Performance: Evidence from Dutch SMEs, *Scientific Analysis of Entrepreneurship and SMEs*, 2007.

Wernerfelt, B. “A Resource-based View of the Firm”, *Strategic Management Journal*, 5:2, 1984, pp 171–180.

Appendix A - Definition of variables

Variables	Description
Innovative performance	Percentage of the total turnover in 2006 from goods and service innovations introduced during 2004 to 2006 that are new to the firm
Propensity to innovate	Equal to 1 if introduced new or significantly improved goods or/and services during the three years 2004 to 2006, 0 otherwise
Organizational innovation practices	
Business practices	Equal to 1 if introduced new business practices for organizing work or procedures (i.e. supply chain, business re-engineering, lean production, quality management), 0 otherwise
Knowledge management	Equal to 1 if introduced new knowledge management systems to better use or exchange information, knowledge, skills within the firm or to collect and interpret information from outside the firm), 0 otherwise
Workplace organization	Equal to 1 if introduced new methods of workplace organization for distributing responsibilities and decision making (team work, decentralization, integration or de-integration of departments), 0 otherwise
External relations	Equal to 1 if introduced new methods of organizing external relations with other firms or public institutions (partnerships, outsourcing, sub-contracting), 0 otherwise
Innovation activities	
R&D intensity	Sum of expenditures for intramural (in-house) R&D and extramural R&D in 2006 divided to total turnover in 2006
In-house R&D	Equal to 1 if engaged in in-house (intramural) R&D, 0 otherwise
Extramural R&D	Equal to 1 if engaged R&D performed by other firms (including other firms within the group), by other public or private organizations, 0 otherwise
Technological acquisition	Equal to 1 if engaged in acquisition of advanced machinery equipment and computer hardware, 0 otherwise
Knowledge acquisition	Equal to 1 if engaged in purchase or licensing of patents and non-patented inventions, know-how and other types of knowledge, 0 otherwise
Information sources	
Public sources	Equal to 1 if the score of importance of at least one of two following sources of information is "crucial" for the firm's innovation activities: (1) universities or other higher education institutions; (2) governments or public research institutes, 0 otherwise
Private sources	Equal to 1 if the score of importance of following source of information is "crucial": consultants, commercial laboratories, or private R&D institutes, 0 otherwise
Market sources	Equal to 1 if the score of importance of at least one of three following sources of information is "crucial": (1) suppliers of equipments, materials, components, or software; (2) clients or customers; (3) competitors or other enterprises in your sector,0 otherwise
Competition context	
Competitors actions	Difficult to forecast the actions of competitors, on a Likert scale (0 to 3)
Market position	Market threatened by the arrival of new competitors, on a Likert scale (0 to 3)
Technological changes	Quick change of the production's technologies and the services, on a Likert scale (0 to 3)
Innovation objectives	
Demand-pull	Sum of scores of importance of three demand-related objectives of innovation, number between 0 (unimportant) and 3 (crucial): (1) increased range of goods or services; (2) entered new markets or increased market share; (3) improved quality of goods or services (rescaled between 0 and 1)
Cost-push	Sum of scores of importance of four cost-related objectives of innovation, number between 0 (unimportant) and 3 (crucial): (1) improved flexibility of production or service provision; (2) increased capacity of production or service provision; (3) reduced labor costs per units output; (4) reduced materials and energy per unit output (rescaled between 0 and 1)
Obstacles to innovation	
Financial obstacles	Equal to 1 if the score of importance of at least one of three following obstacles (scores between 0 (unimportant) and 3 (crucial)) is "crucial": (1) lack of funds within your enterprise; (2) lack of finance from sources outside your enterprise; (3) innovation costs too high, 0 otherwise
Knowledge obstacles	Equal to 1 if the score of importance of at least one of four following obstacles (scores between 0 (unimportant) and 3 (crucial)) is "crucial": (1) lack of qualified personnel; (2) lack of information on technology; (3) lack of information on market, (4) difficulty in finding cooperation partners for innovation, 0 otherwise
Market obstacles	Equal to 1 if the score of importance of at least one of two following obstacles (scores between 0 (unimportant) and 3 (crucial)) is "crucial": (1) market dominated by established enterprises; (2) uncertain demand for innovative goods or services, 0 otherwise
Size, group, sector	
Size	Logarithm of the number of employees
Group belonging	Equal to 1 if no part of group (reference); equal to 2 if part of a national enterprise group; equal to 3 if part of an European enterprise group; equal to 4 if part of extra-European enterprise group
Sectors	High and medium high-tech manufacturing Industry; Medium low tech manufacturing industry; Low tech manufacturing industry; Transport and communication; Financial intermediation; Computer activities; R&D – Engineering activities and consultancy, Technical testing and analysis and Wholesale trade (reference)

Appendix B: Unconditional binary correlations between organizational practices

	Business practices	Knowledge management	Workplace organization	External relations
Business practices	1.00			
Knowledge management	0.54	1.00		
Workplace organization	0.47	0.48	1.00	
External relations	0.32	0.26	0.35	1.00