CEPS/INSTEAD

Centre d'Etudes de Populations, de Pauvreté et de Politiques Socio-Economiques International Networks for Studies in Technology, Environment, Alternatives, Development

Working Paper

Département 'Entreprises'

N°2008-09

Organizational Complementarity in the Innovation Process. Evidence from Luxembourg firms*

Thi Thuc Uyen NGUYEN, CEPS/INSTEAD, Differdange, Luxembourg thithucuyen.nguyen@ceps.lu

Caroline MOTHE, IREGE, Annecy, France
caroline.mothe@univ-savoie.fr

Décembre 2008

CEPS/INSTEAD, 44, rue Emile Mark, L-4501 Differdange – Grand-Duché de Luxembourg

ID: 03-08-0447-E

* We would like to thank committee's members of the conference 11th IBIMA conference proceedings "Innovation and Knowedge Management in Twin Track Economies", 4-6 January 2009 (Cairo, Egypt) for evaluation of acceptance of this paper. We are also grateful to Ludivine Martin for technical help and valuable discussion. Remaining errors are of our entire responsibility.

Organizational Complementarity in the Innovation Process. Evidence from Luxembourg firms*

Thi Thuc Uyen NGUYEN, CEPS/INSTEAD, Differdange, Luxembourg
thithucuyen.nguyen@ceps.lu

Caroline MOTHE, IREGE, Annecy, France
caroline.mothe@univ-savoie.fr

Abstract

The aim of this paper is to investigate the complementarity of different organizational practices in the innovation process. For this purpose, we perform a two-steps analysis: first, analyzing the conditional correlation between practices and second, directly testing the impact of simultaneous combinations of practices on the firm's innovativeness. We use the firm-level dataset drawn from the Luxembourgish Community Innovation Survey (CIS2006) carried out in 2008. The survey provides information on four organizational practices: "business practices", "knowledge management", "workplace organization" and "external relations". Two phases of the innovation process are investigated: the decision to innovate or not, and the innovative performance, conditional that a firm does any innovation at all. The results show that the implementation of new "knowledge management" systems has a significant and positive impact both on the propensity to innovate and the innovative performance. The joint implementation of "workplace organization" and "external relations" raises the firm innovativeness. Furthermore, "workplace organization" and "external relation" are complementary. The results also provide some suggestive support that "business practices" might have a beneficial role on firm innovativeness only if it is simultaneously used with other organizational practices. Overall, the paper shows that the evidence of complementarity in practices of organizational innovation depends on the phase of innovation process as well as the particular pair-wise combination of organizational practices.

Keywords: complementarity, performance, knowledge management, workplace organization, business practices.

* We would like to thank committee's members of the conference 11th IBIMA conference proceedings "Innovation and Knowedge Management in Twin Track Economies", 4-6 January 2009 (Cairo, Egypt) for evaluation of acceptance of this paper. We are also grateful to Ludivine Martin for technical help and valuable discussion. Remaining errors are of our entire responsibility.

1. Introduction

Numerous theoretical contributions, particularly those of Penrose (1959), Nelson and Winter (1982), Wernerfelt (1984), Teece (1988), which constitute the base of a new theory about competences and internal resources (resource-based view) highlight the importance of managing different types of resources. Indeed, firms are constrained to organize the innovation process efficiently by combining technological capabilities with competencies in finance, management and entrepreneurship knowledge. As suggested by Teece (1986, 1988) and 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 complementary assets' management 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, and contacts with clients, etc. Firms should therefore 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 an activity increases the level of the other activity. For example, when a firm invests into organizational innovation activities by introducing knowledge management systems, it becomes easier to develop technological innovations. We here also find the traditional link between strategy and organization, changes in strategy inducing changes in organization and vice-versa. Complementarity giving rise to synergies among the complementary activities, not taking it into account may lead to a loss in value creation, and firm's performance, because it 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 to be able to reap the benefits of its technological innovation. Milgrom and Roberts (1995) emphasizes thus that the various firms' activities, being mutually complementary, must consequently to be adopted together.

Several empirical studies have investigated the presence of synergistic effects that may arise from simultaneous adoption of complementary organizational practices, showing however controversial results (Cappelli and Newmark, 2001; Ichniowski *et al.*, 1997). Although the existing literature has substantially improved our understanding of complementarity, the measures of organizational practices frequently used are limited to new workplace organization, 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 all types of organizational practices which should be considered by the firm. Thus, we wonder to know, first, why some firms decide to invest in organizational innovation and others do not, second, whether synergistic effects of different organizational strategies on performance exist. For this purpose, a two-steps analysis is performed. The first one consists on analyzing the conditional correlation between practices. The second one consists to directly testing the impact of simultaneous combinations of practices on the firm's innovativeness, measured as the probability to be innovator and as the share in sales of innovative products. We use the firm-level dataset drawn from the Luxembourgish Community Innovation Survey (CIS2006) carried out in 2008. It provides information on four organizational practices: business practices, knowledge management, workplace organization and external relations.

The next section reviews the literature on organizational innovation and the different practices. The third section presents the methodology used. The fourth section describes the dataset, the variables and the empirical test. The results are presented in the fifth section.

2. Organizational innovation in literature

Theoretically, *organizational innovation* is a broad concept that encompasses strategies, 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 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, creativity - that 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 decentralized 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 (Sakakibara, 1997; Jacquemin, 1988), to benefit from economies of scale or scope (Kogut, 1988).

3. Approaches for testing the complementarity

The concept of complementarity refers to the existence of systems effects and synergies of alternative activities within the innovation process. 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 the complementarity 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 analysis

The intuition is based on the ideas that complementarity creates 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 in the same direction. However, Athey and Stern (1998) note that two activities could be correlated without being complements or the potential correlation may be hidden by the influence of common set of exogenous factors. In order to take it 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. Although the advantage and the relatively simple use, it does not provide sufficient condition to conclude an eventual relation of complementarity between two activities. It is complementarity which implies, under some conditions, positive correlation while the reverse is not always true (Catozzella and Vivarelli, 2007). Another approach must be carried out for more fully supported conclusions.

3.2 The direct approach: performance analysis

This approach is based directly on the objective function of the firm. The principal 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; Migrom 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 estimate the innovation function and investigate whether policy decisions (i.e. obstacles to innovation that are affected by policies) are complementary. Lokshin *et al.* (2004) study 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 the complementary innovation activities (in-house R&D, external technology sourcing, etc.) and their impact on the 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 inclusive, 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 use a sample of 568 representative firms with a least 10 employees in the manufacturing and the service sectors.

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

[2] Central Service of Statistics and Economic Studies

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 (Cassiman and Veugelers, 2006; Mohnen and Röller, 2005; Mairesse and Mohnen, 2002). In addition, we have also information on whether a firm innovates. The second dependent variable is thus the *propensity to innovate*.

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 main objective of the paper is to investigate the complementarity between these organizational practices.

We also include 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 innovation efforts of the firms. 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.

In the questionnaire, firms are asked to rate the importance of information sources on a Likert scale (0 to 3). We construct 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 introduced also 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). See Appendix A for more precise definitions of variables.

4.3 Empirical tests

For the purpose of this paper, which aims at evaluating complementary relations between different organizational practices, we use a two steps analysis. First, the factors determining the introduction of different practices of organizational innovation are explored, conditional to a set of firm's observable characteristics. For this purpose, we perform a multivariate Probit model which includes four equations estimating the four organizational practices. This method allows 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' where 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 aims at comparing the impacts of alternative combinations of practices on the firm performance. 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 303 firms who declared themselves innovative out of a total of 568, their innovative performance. Heckman's estimation provides a way of estimating treatment effects when the treated sample (our 303 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. This model used also allows testing for complementarity of organizational practices in the propensity to innovate.

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). We 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 innovation activities that consist on acquisition of advanced machinery, equipment and software, affecting both the four practices. We expect that firms investing in technological acquisition, aiming at producing new or significant improved products and processes, should be constrained to reorganize their workforce, to implement new work organization and management systems, and this is 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 (0.009)***	-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 (0.001)***
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)*
Sectors dummies included	yes	yes	yes	yes
Constant	-1.226 (0.000)***	-1.200 (0.000)***	-0.959 (0.001)***	-1.179 (0.000)***
Observation	568			
Log likelihood	-1056.13			
Wald $\chi^2(92)$	228.49***			

Notes: *, ** and *** denote significance at the level of 10%, 5% and 1% respectively. 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 rated as crucial for innovation are found not to be associated with the adoption "workplace organization", "business practices" and "external relations". This is counter-intuitive and in contrast with the recent trends in the literature which emphasize that firms actively develop organizational strategies to maximally 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 are more to introduce new knowledge management systems. This is not surprising considering that one of principal objectives of the knowledge management systems is to allow firms' employees to better use and exchange information, knowledge and skills as well as to collect and interpret 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 the actions of competitors 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, sector is in general not significant. This confirms the intuition that the organizational strategy a firm adopt does not depend on the sector-level but rather on firm-specific characteristics which influence the incentives and ability to innovate. In general, we find few evidence of the impact of ownership on "business practices" and "workplace organization". It is found by contrast that 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 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	-	0.196 (0.052)**
In-house R&D	-0.137 (0.702)	-
Extramural R&D	1.165 (0.011)***	-
Technological acquisition	-0.382 (0.349)	-
Knowledge acquisition	0.004 (0.991)	-
Public sources	0.984 (0.759)	0.043 (0.132)
Private sources	-0.069 (0.973)	-0.011 (0.522)
Market sources	0.878 (0.013)**	-0.007 (0.643)
Financial obstacles	-	0.014 (0.520)
Knowledge obstacles	-	-0.045 (0.012)***
Market obstacles	-	0.042 (0.022)**
Demand-pull	1.226 (0.030)**	0.130 (0.003)***
Cost-push	-0.470 (0.423)	-0.021 (0.479)
Size	0.250 (0.053)**	-0.006 (0.292)
Luxembourg groups	0.089 (0.845)	0.016 (0.558)
European groups	0.077 (0.836)	-0.005 (0.789)
Extra-europe groups	0.290 (0.887)	0.015 (0.546)
Business practices	0.588 (0.830)	0.019 (0.457)
Knowledge management	6.118 (0.000)***	0.133 (0.032)**
Workplace organization	-0.265 (0.877)	0.124 (0.009)***
External relations	6.602 (0.000)***	0.025 (0.432)
Business practices, Knowledge management	-0.025 (0.987)	0.025 (0.401)
Knowledge management, Workplace organization	0.782 (0.786)	-0.011 (0.508)
Business practices, Workplace organization	-0.257 (0.696)	0.013 (0.697)
Business practices, External relations	-1.322 (0.588)	0.014 (0.802)
Workplace organization, External relations	-0.097 (0.975)	0.060 (0.044)**
Business practices, Knowledge management, Workplace organization	0.530 (0.682)	0.027 (0.268)
Business practices, Workplace organization, External relations	0.152 (0.950)	0.018 (0.675)
Knowledge management, Workplace organization, External relations	3.153 (0.383)	-0.098 (0.025)**
Business practices, Knowledge management, External relations	5.650 (0.000)***	0.015 (0.762)
Business practices, Knowledge management, Workplace organization, External relations	-0.027 (0.954)	0.045 (0.132)
Sectors dummies included	yes	yes
Constant	-0.706 (0.354)	-0.038 (0.509)

Notes: *, ** and *** denote significance at the level of 10%, 5% and 1% respectively. 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 depends on extramural R&D investment, while the innovative performance on the intensity to R&D. This is in line with previous empirical findings indicating the crucial role of own R&D expenditures for the innovation process as they condition the knowledge creation as well as the firms' capacity to absorb external knowledge (Grilliches and Mairesse, 1984; Crépon *et al*., 1998). The results also show that

sources of information coming from the market matter for propensity to innovate. In turn, any information sources are found to be associated with the innovative performance. Regarding the obstacles to innovation, which are included only in the estimation model for innovative innovation, significant and positive effects are found. 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, while no such evidence is found for the innovative performance. Lynch and Black (1998) find that smaller firms are much less likely to provide organizational programs than larger firms. The absence of positive impact of size on the innovative performance could be due to mechanical effects as small innovating firms have a smaller product portfolio: thus, when small firms engage in product innovation activities, the part of those innovations will be higher in the overall turnover than for large firms, for which innovative activities are much more diffused. Being part of a group, domestic or international, does not matter. We also find a significant and positive effect of demand-pull on propensity to innovate and firm performance.

Looking at the impact of organizational practices, the results show that new "knowledge management" systems, when separately adopted has a significant and positive impact both on the propensity to innovate and the innovative performance. This is 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). 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.

Performing "workplace organization" also significantly raises the firm 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. "External relations"

also have significant and positive impact on the innovative performance. This might be explained by the interest of this organizational practice allowing firms to access partners' complementary or synergistic competencies and capitalize "*incoming spillovers*", to reduce the duplication of R&D efforts as well as risks and costs associated to innovation projects (Kogut and Zander, 1993; Cassiman and Veugelers, 2002; Sakakibara, 1997; Jacquemin, 1988).

The results also find that four pair-wise combinations of practices[3] are not significant. The absence of such a relation may be partially due to the substantial time lag usually associated with the return on investment of such long-maturity strategy (Askenazy, 2000). When implementing organizational changes such as new "workplace organization" or "business practices", firm's employers and employees are involved in a long run process of adaption and learning which does not result immediately in substantial improvement in innovative performance.

In particular, it is interesting to observe that the joint implementation of "knowledge management" and "workplace organization" does not have any significant additional impact on innovative performance, while "knowledge management" or "workplace organization" separately performed significantly pays off more in terms of financial returns. This result could suggest the substitutability between these two organizational practices.

The estimated coefficient on the joint implementation of "workplace organization" and "external relations" is significant and positive regarding the innovative performance, while it does not matter as far as the propensity to innovate is concerned. It thus suggests that simultaneous implementation of "workplace organization" and "external relation" pays off more than the isolated adoption of each of them. In contrast, this joint adoption, when added to a third practice such as "knowledge management", turns to be negatively associated with the innovative performance. Overall, "workplace organization" and "external relations" are complements in the innovative performance, while substitutable as far as combined with "knowledge management".

[3] "business practices" and "knowledge management", "knowledge management" and "workplace organization", "business practices" and "workplace organization", "business practices" and "external relations"

Finally, we observe that "business practices", "knowledge management" and "external relations" seem to be complementary as far as the propensity to innovate is concerned, as evident by the significance of the associated coefficient. Recall that "knowledge management" or "external relations" (separately adopted) raises the probability of becoming an innovator, as mentioned above, while it is not the case for "business practices". Overall, these results could suggest that "business practices" might have a beneficial role on firm innovativeness only if it is simultaneously used with other organizational practices. This is in line with the existing literature emphasizing that firms have opportunities for higher innovative performance being able to work with external partners, to exploit information from outside as well as reorganize workplace and procedures by introducing practices such as business re-engineering, lean production, quality management, etc. (Kogut and Zander, 1993; Ichniowski *et al.*, 1997; Ichniowski and Shaw, 2003)

6. Conclusion

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

Regarding the factors that determine the implementation of innovation organizational, we find that the innovation activities such as 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". Significant and positive coefficients are also found regarding the innovation activities that consist on acquisition of advanced machinery, equipment and software, affecting both the four practices. The perception of market-related obstacles to innovation has significant and negative impact on the adoption of organizational practices. We find furthermore 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 controlled. Through the performance approach, less significant pair-wise combinations are significant. We find for example that the "business practices" and the "knowledge management" are strongly correlated while not complements. This means, firms which perform business practices are more likely to adopt new knowledge management systems, and vice versa, but implementing the one type of practice does not make the other more valuable in terms of innovativeness. Other underlying factors (unobserved) may cause the correlation instead of complementarity.

With the performance approach, two organizational practices are considered as complements if these innovative strategies are mutually reinforcing because increasing the level of any of them increases the marginal profitability of the other (Milgrom and Roberts, 1990). According to this, we find that the implementation of new "knowledge management" systems has a significant and positive impact both on the propensity to innovate and the innovative performance. The joint implementation of "workplace organization" and "external relations" is significant and positive, while it does matter as far as the propensity to innovate is concerned. The estimated coefficient on the joint implementation of "workplace organization" and "external relations" is significant and positive, while it does matter as far as the propensity to innovate is concerned. It thus suggests that "workplace organization" and "external relation" should be complementary. In contrast, this joint adoption, when added to a third practice such as "knowledge management", turns to be negatively associated with the innovative performance. "Workplace organization" and "external relations" are complements in the innovative performance, while substitutable as far as combined with "knowledge management". The results also provide some suggestive support that "business practices" might have a beneficial role on firm innovativeness only if it is simultaneously used with other organizational practices. Overall, the paper shows that the evidence of complementarity

in practices of organizational innovation depends on the phase of innovation process as well as the particular pair-wise combination of organizational practices.

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
Informations 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 innovate	
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, sectors	
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

References

[1] 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.

[2] 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.

[3] 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.

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

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

[6] 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.

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

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

[9] 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.

[10] 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.

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

[12] 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.

[13] Dougherty, D. "A Practice-Centered Model of Organizational Renewal through Product Innovation", *Strategic Management Journal* (23), 1992, pp 77–92.

[14] European Commission's Green Paper, 1997, from 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.

[15] 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.

[16] Grant, R.M. "Toward a Knowledge-base Theory of the Firm", *Strategic Management Journal*, (17), 1996, pp 109–122.

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

[18] 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.

[19] 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.

[20] Heckman, J. "Sample selection bias as a specification error", *Econometrica* (47), 1979, pp 153–161.

[21] 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.

[22] 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.

[23] 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.

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

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

[26] 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.

[27] 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.

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

[29] 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.

[30] 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.

[31] 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.

[32] Ménard, C. “La Nature de l’Innovation Organisationnelle”, *Revue d’Economie Industrielle* (Numéro Exceptionnel), 1994, pp 173-192.

[33] 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.

[34] Mohnen, P., and Röller, L. “Complementarities in innovation policy”, *European Economic Review* (49), 2005, pp. 1431-1450.

[35] 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.

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

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

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

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

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

[41] 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.

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

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

[44] 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.

[45] Teece, D.J. "Profiting from technological innovation", *Research Policy*, (15), 1986, pp 285–305.

[46] 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.

[47] Topkis, D.M. Supermodularity and Complementarity, Princeton, NJ, 1998.

[48] Uhlaner, L., and 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.

[49] Wernerfelt, B. "A Resource-based View of the Firm", *Strategic Management Journal* (5:2), 1984, pp 171–180.