CEPS
INSTEAD

WORKING PAPERS

Synergistic effects of organizational innovation practices and firm performance

Caroline MOTHE[1]
Uyen T. NGUYEN-THI[2]
Phu NGUYEN-VAN[3]

IREGE, University of Savoie, France[1]
CEPS/INSTEAD, Luxembourg[2]
BETA-CNRS, University of Strasbourg, France[3]

Working Paper No 2011-32
May 2011

Synergistic effects of organizational innovation practices and firm performance

Caroline Mothe
IREGE, University of Savoie, France
Caroline.Mothe@univ-savoie.fr

Uyen T. Nguyen-Thi*
CEPS/INSTEAD, Luxembourg
thithucuyen.nguyen@ceps.lu

Phu Nguyen-Van
BETA-CNRS, University of Strasbourg, France
Phu.Nguyen-Van@cournot.u-strasbg.fr

Abstract

Organizational innovation has been shown to be favourable for technological innovation. However, the question of which organizational practices should be combined – and thus of their compatibility – remains unanswered. We here empirically investigate the complementarities between different organizational practices (business practices, knowledge management, workplace organization and external relations). Firm-level data were drawn from the Community Innovation Survey (CIS) carried out in 2008 in Luxembourg. Supermodularity tests provide evidence of the impact of complementary asset management to raise firms' innovative performance. The organizational practices' combinations differ according to whether the firm is in the first step of the innovation process (i.e. being innovative) or in a later step (i.e. performing as far as innovation is concerned). When adopting organizational practices, managers should therefore be aware of their effects on technological innovation. These results also have implications for public policies in terms of innovation support.

Keywords: Complementarities, Organizational innovation, Technological innovations, Supermodularity, Innovative performance

*Corresponding author. Thi T. Nguyen-Thi, CEPS/INSTEAD, 3, avenue de la Fonte, 4364 Esch-sur-Alzette, Luxembourg; tel.: (352)585855632; fax: (352)585560; e-mail: thithucuyen.nguyen@ceps.lu

1. Introduction

The study of innovation, an ongoing priority in most developed countries, mainly deals with technological aspects, and research in the field has essentially focused on inputs and support instruments. Empirical works have given limited attention to other innovation strategies such as those implemented in the organizational field. We here investigate the links between organizational and technological innovations. Indeed, it is now recognized that innovation processes are highly interactive in nature and that non-technological activities play a crucial role: "firms are inter-dependent in their innovation activities" (Tether and Tajar, 2008: 722). The importance of managing different types of resources has long been highlighted by the resource-based view and evolutionary economics (e.g. Penrose, 1959; Nelson and Winter, 1982; Wernerfelt, 1984; Teece, 1988), but the notion of complementary assets (Teece, 1986) remains largely untested. Indeed, Stieglitz and Heine (2007: 1) underlined that "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". Also, when tests do exist, they often provide contradictory results (Schmiedeberg, 2008).

This lack of empirics is especially blatant as far as innovation activities are concerned, even though Teece (1986) established that complementary assets (such as marketing or organizational capabilities, regulatory knowledge, contact with clients, etc.) raise the value of firms' technological innovations. Indeed, complementary assets help innovators to appropriate Schumpeterian rents successfully as they constitute important barriers to imitation. Stieglitz and Heine (2007) theoretically emphasized the impact of managing complementary assets on firms' innovativeness. In line with these authors, we see assets or activities as mutually complementary if the marginal returns of one activity increase the level of the other activity. Complementarities give rise to synergies among the complementary activities; not taking this 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 sales organization, the creation of which the firm does not undertake, the firm might not be in a position to be able to reap the benefits of its technological innovation.

Several empirical studies have investigated the presence of synergistic effects that may arise from the 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 have been 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 have not usually been taken into account. Therefore, alternative organizational practices have not been studied together.

Knowledge of these complementarities should pave the way for the creation of sustainable competitive advantage as the increase in the strategy's complexity acts as a barrier to potential imitators (Rivkin, 2000). Building upon the existing literature, this paper investigates the complementarities between four types of organizational practices: business practices, knowledge management, workplace organization and external relations. To our knowledge, this is the first empirical study to examine the complementarities between organizational innovations and their effect on technological innovation, analysing the multiple complementarities between these four practices. It provides empirical evidence of the synergistic effects of different organizational strategies on innovative performance. A two-step analysis is performed, as used similarly by Cassiman and Veugelers (2002, 2006), Galia and Legros (2004) and Mohnen and Röller (2005), with an analysis of the conditional correlation between practices as well as a direct performance approach to the impact of simultaneous combinations of practices on the firm's innovative performance.

The article is structured as follows. Section 2 reviews the existing empirical literature on organizational innovation and complementarities. Section 3 describes the data set from the Luxembourg CIS 2006 and the variables used. Section 4 presents the methodology for testing complementarities. The estimation results are presented and discussed in Section 5 while conclusive remarks and future directions for research are given in the last section.

2. Organizational innovation and literature on complementarities

2.1. Organizational innovation

Innovation is a widely used concept and the term's definition varies to reflect the particular requirements and characteristics of specific research (Damanpour and Evan, 1984). Becker and Whisler suggested that innovation is "the first or early use of an idea by one of a set of organizations with similar goals" (1967: 463). Innovation (or "organizational

innovation") has also been defined as the adoption of an idea or behaviour that is new to the organization (Mohr, 1969; Aiken and Hage, 1971; Daft, 1978).

The definition adopted for this research is in line with Damanpour and Evan (1984), who distinguish between technical and administrative innovations. Technical innovations are innovations that occur in the technical system of an organization and are directly related to the primary work activity of the organization. A technical innovation can be the implementation of an idea for a new product or a new service or the introduction of new elements into an organization's production process or service operation. Technical innovations are perceived here as a means to change and improve the performance of the technical system of an organization. Administrative innovations are defined as those that occur in the social system of an organization. The social system here refers to the relationships among people who interact to accomplish a particular goal or task (Cummings and Srivastva, 1977). It also includes those rules, roles, procedures and structures that are related to communication and exchange among people and between the environment and people. An administrative innovation comprises innovations in the organizational structure and in the management of people (Knight, 1967).

In this investigation, organizational innovations are thus considered to be administrative innovations as defined by Damanpour and Evan (1984), involving the implementation of a new administrative idea. The adoption of a new idea in an organization is expected to result in an organizational change that might affect the technological innovative performance of that organization. In this study, we look at the impact of combined organizational innovations on technological (or "technical", Damanpour and Evan, 1984) innovative performance, and more specifically on *product technological innovation*, defined as the introduction of goods or services that are new or significantly improved with respect to their specifications or intended uses.

2.2. Literature on complementarities

Research in the fields of industrial organization, strategic management and innovation has long assumed the existence of complementarities, which may result in economies of scope. However, empirical research has reached unclear conclusions (Schmiedeberg, 2008). Firms that are active in technological innovation usually adopt complementary organizational practices. Kimberly and Evanisko (1981) found positive associations between administrative and technical innovations. Ettlie (1988), studying administrative and technological

innovations in the manufacturing sector, found that successful firms adopt the two types of innovations simultaneously. Damanpour and Evan (1984), using the socio-technical systems framework, linked the positive association between administrative and technical innovations to the requirement for a balance between the social and the technical systems of the organization.

Numerous studies have investigated this complementarity, or the associated adoption, between organizational and technological innovations by highlighting the importance of technological innovation as a driver of organizational changes within the firm (Henderson and Clark, 1990; Dougherty, 1992). These studies focused on the fact that technological innovation is usually conducive to organizational innovation. Firms introducing technological innovation would therefore be constrained to reorganize their production, workforce, sales 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 technological innovation (Greenan et al., 1993). Using a sample of firms in the fast-moving consumer goods industry in Germany, Lokshin et al. (2008a, 2008b) 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 in competitive advantage and firm performance is acknowledged.

Focusing on the complementarities in terms of innovation, a large stream of literature is dedicated to the complementarities between input factors, such as in the relation between internal and external R&D (such as Love and Roper, 2001; Cassiman and Veugelers, 2002, 2006; Beneito, 2006; Colombo et al., 2006; Schmiedeberg, 2008). Audretsch et al. (1996) paved the way, suggesting that the relationship between different types of R&D may differ between industries; in low-tech industries, internal and external R&D were found to be substitutes, whereas in high-tech industries they appeared to act as complements. Schmiedeberg (2008) provided new insight into the complementarity of different innovation activities, showing that internal R&D, R&D contracting and R&D cooperation are not always complements, although not considering multiple complementarities. In a different manner, looking at innovation as a process (rather than as an event, even if some studies acknowledge two main stages), Love and Roper (2009a) focus on the complementarity between innovation networking and the use of external knowledge in four different stages of the innovation process. However, it should be noted that the term "complementarity" is often misused.

Indeed, some authors refer to "complementarity" or to "complementary assets" when they find a positive correlation between different types of R&D – which is far from meaning, in the absence of complementarity tests (which are subject to discussion, see Section 4 and Carree et al., 2010), that these activities are complementary.

Another, more diffuse, stream of research analyses different types of innovation complementarities such as between process and product innovation – and, more largely, among production and innovation strategies (Miravete and Pernias, 2006), labour skills and innovation strategies (Leiponen, 2005), obstacles to innovation and different government innovation policies (Galia and Legros, 2004; Mohnen and Röller, 2005), information technology, workplace reorganization and new product and service innovations (Bresnahan et al., 2002; Black and Lynch, 2005), cross-functional teams (Love and Roper, 2009b) or multiple adoption of new process technologies (Gomez and Vargas, 2009).

Our paper is in line with a third stream of research on innovation complementarities, namely that between organizational innovation strategies and the effect on technological innovative performance. When studying organizational practices, authors have essentially looked at external R&D relations, following Arora and Gambardella (1990). It thus appears as a "complement" to the previously cited works on the combinations of various R&D activities. Recent empirical studies of organizational performance have been concerned with establishing potential complementarity between more than two organizational practices adopted simultaneously (see Carree et al., 2010, for a review). However, empirical research on complementarities between different innovation strategies remains scarce, with the exception of works on networking and external relations – the most-studied organizational innovation practice since the seminal study of Arora and Gambardella (1990), who found that the strategies of external linkage of large firms with other parties are complementary to one another. Belderbos et al. (2006) tested, with an emphasis on the methodological aspects of strict supermodularity and thanks to two waves of the biannual Dutch Community Innovation Surveys (CIS) data, whether different types of R&D cooperation are complementary in improving productivity (especially for small firms). Research is only beginning to shed some light on the relationship between technological and non-technological innovation, a "very complex and under-investigated topic" (Evangelista and Vezzani, 2010: 1262). These authors provide evidence that enlarging the analysis of innovation beyond the technological domain is crucial to a better understanding of firms' economic performances, complex and organizational innovation modes playing a major role in explaining these performances. Our

objective is different as we aim to identify complementarities between organizational innovation practices and their impact on technological innovative performance.

Very few studies on such complementarities have been identified. Lhuillery (2000) focused on a range of individual organizational practices (mostly knowledge production and human management practices) and identified those that affect the innovation capability of French companies. The results show that innovative firms tend to cluster their organizational practices. Lhuillery's (2000) research matched the CIS2 database and the "Competency Survey", thus encompassing different organizational practices from the one in the latest CIS. Moreover, the author used dependent variables such as patents, process, product, marketing and design innovation, while we focus on technological innovation (process and product). Cozzarin and Percival (2006) studied complementarities between organizational strategies and novel innovations. The sixteen organizational variables were regrouped into four factors: "hiring focus", "research and development", "market focus" and a combination of satisfying existing clients, promoting reputation, hiring experienced employees and training, called "reputation focus". The most important finding is that innovation is complementary to many organizational strategies. Our work is in line with that of Cozzarin and Percival (2006), with notable differences regarding both the dependent variables (profit or labour productivity vs. innovation and innovative performance representing two stages of the innovation process) and the independent variables (four different organizational practices), as well as the database (1999 Canadian Survey of Innovation vs. Luxembourg CIS 2006).

3. Data and variables

3.1. Data

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 was to collect data on firms' innovation behaviour, over the three-year period from 2004 to 2006, according to the OECD (2005) recommendations. It provides a set of firms' general information (sector of activities, group belonging, number of employees, sales, geographic market), information about

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

[2] Central Service of Statistics and Economic Studies
[2] Central Service of Statistics and Economic Studies

technological and non-technological innovation as well as perceptions of factors hampering innovation activities or subjective evaluation of the effects of innovation. The data set 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 sub-sample of firms with at least 10 employees in the manufacturing and the service sectors. With the data set including manufacturing and service firms, the paper adopts the *synthesis* approach, which allows for innovation to take place in manufacturing *and* in services (Gallouj and Weinstein, 1997; Love and Mansury, 2007).[3] We thus obtain a sample of 551 representative firms.

3.2. Variables

Two dependent variables are used. The first one, *innovative performance*, is measured as the percentage of the total turnover from product innovations that are new to the firm (Mairesse and Mohnen, 2002; Mohnen and Röller, 2005; Cassiman and Veugelers, 2006). The second dependent variable, *propensity to innovate*, refers to whether the firm had introduced product innovation or not (cf. Appendix A for definitions of all the variables).

The CIS provides data on organizational innovation implemented by firms 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 constructed for each of these practices. The objective of the paper is to investigate the complementarity between these organizational practices.

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 and quality management. The second category of organizational innovation refers to the introduction of knowledge management systems. Knowledge management, here including complementary practices such as management skills, up-skilling of employees, sharing, codification and storage of knowledge, is usually associated with greater 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 changes to the

[3] Moreover, doing so would create a problem of missing observations, which could seriously affect the quality of the regressions.

work organization. The European Commission's Green Paper (1997) sees it as a key priority for higher competitiveness, based on high skill, trust and quality. For the OECD (2005), new work practices are related to decentralized decision-making, job rotation, teamwork 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 the evolutionary and continual character of the learning process, innovative firms should concentrate on their specific capabilities while involving themselves in cooperative arrangements in order to develop new competencies and extensions of the firm's know-how to new applications. Moreover, firms should be encouraged to engage in external relations in order to access partners' complementary or synergistic competencies and to capitalize on "incoming spillovers" (Kogut, 1988; Kogut and Zander, 1993; Cassiman and Veugelers, 2002), to reduce the duplication of R&D efforts as well as the risks and costs associated with innovation projects (Jacquemin, 1988; Sakakibara, 1997) or to benefit from scale economies (Kogut, 1988).

Among the explanatory variables, we include the *R&D intensity*, which is measured as the sum of expenditures on intramural (in-house) R&D and extramural R&D in 2006 divided by the total turnover in 2006. Moreover, in order to asset the impact of competition on a firm's decision to adopt organizational innovation, six variables are introduced, describing the characteristics of the competitive context, taking a value on a Likert scale from 0 (no effective competition) to 4 (very intense): (1) *competitors' actions*, describing the actions of competitors that are difficult to forecast; (2) *market position*, referring to the position on the market that is threatened by the arrival of new competitors; (3) *technological changes*, when the production's technologies and the services are changing quite quickly; (4) *product changes*, referring to the products and services that are rapidly becoming old-fashioned; (5) *product substitute*, referring to the fact that the products of the firm can be easily replaced by the products of competitors; and (6) *demand forecast*, when the evolution of the demand is difficult to forecast. Numerous theoretical and empirical studies have investigated the relationship between competition and innovation; however, they have delivered contradictory predictions (Dixit and Stiglitz, 1977; Schmutzler, 2007). The differences related to the assumptions on competition types and on technological characteristics partially explain these

inconclusive claims. Aghion et al. (2005) showed that innovation initially increases with intense competition but then declines, thus predicting an inverted-U relationship between competition and innovation. We here expect a positive relationship between competition and organizational innovation.

Moreover, in order to assess the impact of the innovation obstacles perceived by firms on technological and organizational innovations, we include in the model various variables. In the questionnaire, firms are asked to evaluate the importance of obstacles to innovation. We constructed three dummy variables according to the obstacles' importance. The first one is *financial obstacles*, indicating whether the importance of a lack of funds or/and high costs of innovation is crucial or not. We expect that firms perceiving high costs as an obstacle to innovation are more discouraged from engaging in long and costly organizational and technological strategies (Galia and Legros, 2004; Mohnen and Röller, 2005; Lynch, 2007). The second one is *knowledge obstacles*, indicating whether the importance of a lack of qualified personnel or/and a lack of information on technology or on the market or/and difficulty in finding cooperation partners is crucial or not. Knowledge and information are crucial for innovation activities. We expect that firms with greater skill resources and information are more likely to invest in organizational innovation while the perception of a lack of knowledge and information may reinforce uncertainty, which could hamper the firm's capacity to introduce technological innovation (Lynch, 2007). Finally, we include *market obstacles*, which indicates whether the importance of uncertainty of product demand or/and the dominance of established firms is crucial or not.

Firm size is measured by the natural logarithm of the number of employees. We also introduce a dummy variable of group belonging, taking the value 1 if the firm is independent (reference), 2 if the 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 industry; (3) low-tech 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.

4. Methodology: 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.

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, two approaches are usually made use of in the literature (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 of testing the contribution of different combinations of practices directly on the firm innovative performance (also called "performance" analysis).

4.1. The indirect approach: correlation or adoption analysis

The intuition is based on the idea that complementarities create a force in favour of positive correlation between two activities. If alternative activities are complementary, then we would expect rationally behaving firms to exploit this opportunity, investing in these activities at the same time and in the same direction. However, Athey and Stern (1998) noted 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 complementarity (substitutability) between two activities.

This approach has been by far the most simple and popular among empirical researchers for testing complementarity (Arora and Gambardella, 1990; Ichniowski et al., 1997; Galia and Legros, 2004). The advantage of this approach is the provision of some supportive evidence of complementarity if activities are adopted simultaneously without requiring any performance measure. Despite this advantage and its relatively simple use, it does not provide a sufficient condition to conclude that an eventual relation of complementarity exists between two activities. It is complementarity that 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 obtain more fully supported conclusions.

We here evaluate the complementary relations between different organizational practices by exploring the factors determining the introduction of different practices of organizational innovation, conditional on a set of firm's observable characteristics. We thus perform a multivariate probit model that 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.

4.2. 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 the considered activities, interpreted as parameters of complementarities. Comparing the impacts of alternative combinations of activities stemming from this estimation allows the detection of the complementarity between these activities. One can obtain 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 supermodularity (Milgrom and Roberts, 1995; Topkis, 1998). The intuition is that whenever activities are complementary, the objective function is supermodular. Note that the related definition of supermodularity provided by Milgrom and Roberts (1995) only requires a non-negative (rather than a positive) impact of one practice on the marginal returns of another practice.

Applying this approach, Mohnen and Röller (2005) directly estimated the innovation function and investigated whether policy decisions (i.e. obstacles to innovation that are affected by policies) are complementary. Lokshin et al. (2008a) studied the complementarity between product, process and organizational innovations and their impact on labour productivity. Ichniowski et al. (1997) also used this approach to test the complementarity between different human resource management practices. They found, in 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 a higher output level and product quality. This approach was also used by Cassiman and Veugelers (2006) to investigate complementary innovation activities (in-house R&D, external technology sourcing, etc.) and their impact on firm performance.

In the present paper, we use the direct approach (or performance approach) to test the complementarity by estimating the "innovation function"; alternative combinations of organizational practices being included as explanatory variables. The performance approach focuses directly on the relation between innovative performance and different practices of

organizational innovation. This is in order to compare the impact of alternative combinations of practices on firm performance. Carree et al. (2010) pointed out that this approach, which uses multiple-restrictions tests, is generally superior to the previous one for performance models. Similarly to Mohnen and Röller (2005), we estimate the function that takes the following form:

$$I_i = \sum_{k=0}^{15} S_k \gamma_k + X_i^{'} \alpha + \varepsilon_i \quad (1)$$

where I_i is the innovative performance of firm *i*, measured as the share in sales of innovative products (PERFOR). According to the performance approach, a set of state dummy variables S_k is inserted into the model. As four organizational practices are considered, we obtain sixteen dummy variables *s0_0_0_0, s0_0_0_1, ..., s1_1_1_1*, where the four indices denote the four practices, respectively, i.e. business practices, knowledge management, workplace organization and external relations. X_i represents the set of explanatory variables, including controls for firm-level heterogeneity such as firm size, sectors of activities and foreign ownership as well as a set of variables that have previously been shown to be relevant determinants of innovative performance at the firm level, such as the intensity of internal and external R&D and obstacles to innovation.

Since the dependent variable measures the percentage of the total turnover from innovative products, we only draw on the sub-sample of innovative firms (259) from the data set (551). Therefore, left-censoring arises when many firms in our sample do not innovate at all. If censoring is not accounted for, the estimation of innovative performance could be biased and misleading. In order to correct for censoring and to assess the impact of organization and marketing innovations on the probability of firms becoming innovative, and as the probability to innovate and the financial success of innovative products represent two separate phases of the innovation process, we specify a probit model for the probability to innovate. The function of probability to innovate is written as follows:

$$P_i^* = \sum_{k=0}^{15} S_k \delta_k + W_i^{'} \beta + \upsilon_i \quad (2)$$

where P_i^* is the latent variable corresponding to the probability to innovate. W_i is the set of control variables, including firm size, sectors of activities, foreign ownership and obstacles to innovation.

Afterwards, we perform supermodularity and submodularity tests for complementarity and substitutability, respectively, in organizational practices based on consistent estimates of coefficients γ_n (Equation 1). As in Mohnen and Röller (2005), complementarity between each pair of practices should satisfy the following constraints:[4]

(practices 1 and 2) $\gamma_{8+s} + \gamma_{4+s} \leq \gamma_{0+s} + \gamma_{12+s}$ where $s = 0,1,2,3,$

(practices 1 and 3) $\gamma_{8+s} + \gamma_{2+s} \leq \gamma_{0+s} + \gamma_{10+s}$ where $s = 0,1,4,5,$

(practices 1 and 4) $\gamma_{8+s} + \gamma_{1+s} \leq \gamma_{0+s} + \gamma_{9+s}$ where $s = 0,2,4,6,$

(practices 2 and 3) $\gamma_{4+s} + \gamma_{2+s} \leq \gamma_{0+s} + \gamma_{6+s}$ where $s = 0,1,8,9,$

(practices 2 and 4) $\gamma_{4+s} + \gamma_{1+s} \leq \gamma_{0+s} + \gamma_{5+s}$ where $s = 0,2,8,10,$

(practices 3 and 4) $\gamma_{2+s} + \gamma_{1+s} \leq \gamma_{0+s} + \gamma_{3+s}$ where $s = 0,4,8,12.$

The substitutability between each pair of practices should satisfy the analogous inequalities, which are however of opposite signs.

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: $h_0 \geq 0$ 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 from our regressions because of collinearity, we therefore include in our tests the constraint $\gamma_5 = 0$. The tests for other pairs are defined analogously.

[4] Recall that practices 1 to 4 denote business practices, knowledge management, workplace organization and external relations.

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 $h_3 \leq 0$

We can also perform the same tests of complementarity and substitutability for the probability to innovate equation (Equation 2). These tests are defined very analogously with the γ_k s replaced by δ_k s.

5. Results and discussion

5.1. The indirect approach

The results of the multivariate probit model for the complete sample of 551 observations are presented in Table 2. From this estimation, the conditional pair-wise correlations 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" and between "workplace organization" and "knowledge management". Overall, these results provide some suggestive support for 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 the practices (Belderbos et al., 2006).

Table 1. Conditional correlations between organizational practices

	Business practices	Knowledge management	Workplace organization	External relations
Business practices	1.000			
Knowledge management	0.723***	1.000		
Workplace organization	0.644***	0.724***	1.000	
External relations	0.533***	0.555***	0.647***	1.000

Looking at the determinants of the decision to invest in different organizational practices, firms that face a lack of organizational resources, i.e. qualified personnel, information on technology, information on the market or difficulties in finding cooperation

partners for innovation, are more likely to invest in organizational innovation than those firms not facing such problems. Within the innovation process, some firms may decide to introduce new organizational practices that could result in improvements in organizational flexibility, which could lead in turn to better communication and knowledge sharing within the firm as well as better absorption of knowledge and abilities, which they lack.

Table 2. Results of the multivariate probit model for organizational practices

	Business practices	Knowledge management	Workplace organization	External relations
Size dummies				
50–99 employees	-.04 (.750)	-.21 (.183)	-.17 (.241)	-.09 (.577)
100–249 employees	.36 (.037)**	.29 (.081)*	.29 (.083)*	-.05 (.773)
Over 250 employees	.85 (.000)***	.50 (.004)***	.54 (.002)***	.59 (.001)
Domestic groups	.34 (.038)**	.42 (.010)**	.05 (.724)	.32 (.054)
European groups	.19 (.218)	.19 (.211)	.21 (.140)	.15 (.333)
Extra-Europe groups	.21 (.318)	.29 (.155)	.32 (.106)	-.21 (.370)
Sector dummies	yes	yes	yes	yes
Financial obstacles	.25 (.107)	.147 (.342)	.11 (.460)	.18 (.288)
Knowledge obstacles	.33 (.026)**	.44 (.002)***	.53 (.000)***	.31 (.037)
Market obstacles	-.35 (.017)**	-.27 (.067)**	-.32 (.023)**	.02 (.844)
Competitors' actions	.17 (.011)**	.15 (.018)**	.15 (.017)**	.12 (.088)
Market position	.02 (.801)	.12 (.055)*	.01 (.817)	-.23 (.001)
Technological changes	-.02 (.716)	-.13 (.047)**	-.10 (.104)	-.21 (.003)
Product changes	-.09 (.379)	.01 (.849)	-.07 (.150)	.11 (.078)
Product substitute	.06 (.407)	.04 (.537)	.08 (.207)	.02 (.800)
Demand forecast	-.00 (.941)	.07 (.305)	.08 (.257)	.07 (.338)
Intercept	-.78 (.004)***	-1.12	-.69 (.009)***	-94 (.001)
Observation	551			
Log likelihood	-1081.25			
Wald $\chi^2(92)$	184.39			

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

Surprisingly, the perception of market-related obstacles to innovation has a significant and negative impact on the adoption of the first three organizational practices. In other words, the perception of this type of obstacle, i.e. the domination of the market by well-established firms and the uncertainty about the demand for innovative goods and services, discourages the firm's decision to engage in organizational innovation. We do not find any evidence of the relationship between the financial obstacles variable and all the organizational practices.

Another interesting result is that the competition context on the firms' main market is likely to motivate firms to introduce various practices of 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 Nickell et al. (2001) and 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. The threat of the arrival of new competitors on the market is associated with higher adoption of new knowledge management systems, while this practice seems to be discouraged when the market is characterized by quick changes in the production's technologies and the services.

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 little evidence of the impact of ownership on "business practices" and "workplace organization". By contrast, firms belonging to a domestic group have a higher probability of introducing "knowledge management" systems compared with non-group-belonging firms. Firm size is an important determinant of the introduction of "business practices", "workplace organization" and "knowledge management". Firms with a higher fraction of production workers and a 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 "external relations".

5.2. The direct approach

Based on the adoption approach, our results provide some suggestive evidence of complementarity between the four considered organizational practices. In order to investigate this complementarity further, let us now turn to the direct approach, which consists of directly estimating the performance function of the firm by using the generalized Tobit model. The estimation results of this approach are reported in Table 3.

As the dependent variables in Equations 1 and 2 are respectively the percentage of sales due to innovative products and the probability to innovate, consistent estimates for the parameters of interest can be obtained by maximum likelihood estimation, which accounts for censoring in innovative performance (Mohnen and Röller, 2005). The inverse Mill's ratio included in the model for correcting left-censoring is, however, not significant. This indicates that the estimation results for sales of innovative products are not influenced by censoring.

Table 3. Results of the generalized Tobit model

	Propensity to innovate	Innovative performance
R&D intensity	37.490 (0.000)***	0.215 (0.000)***
Financial obstacles	0.327 (0.090)*	0.016 (0.377)
Knowledge obstacles	0.076 (0.663)	-0.033 (0.054)*
Market obstacles	0.214 (0.207)	0.039 (0.024)**
Size	0.233 (0.000)***	-0.012 (0.081)*
Luxembourg groups	0.399 (0.035)**	-0.002 (0.914)
European groups	0.432 (0.010)***	-0.014 (0.462)
Extra-Europe groups	0.819 (0.002)***	-0.005 (0.835)
Himedhitech	0.447 (0.082)*	-0.001 (0.968)
Metech	-0.317 (0.181)	0.035 (0.207)
Lowtech	-0.347 (0.161)	0.011 (0.716)
Transport	-0.738 (0.001)***	0.024 (0.454)
Finan	0.220 (0.376)	0.043 (0.089)*
Comp	-0.448 (0.126)	0.009 (0.756)
Rd	-0.046 (0.875)	-0.022 (0.488)
s0_0_0_0	-1.785 (0.000)***	0.107 (0.045)**
s0_0_0_1	0.507 (0.438)	0.082 (0.192)
s0_0_1_0	-1.622 (0.000)***	0.232 (0.000)***
s0_0_1_1	-1.454 (0.002)***	0.143 (0.042)**
s0_1_0_0	-1.070 (0.053)*	0.211 (0.003)***
s0_1_1_0	-0.122 (0.820)	0.080 (0.109)
s0_1_1_1	-3.067 (0.006)***	0.025 (0.835)
s1_0_0_0	-1.321 (0.001)***	0.124 (0.027)**
s1_0_0_1	-2.026 (0.005)***	0.132 (0.109)
s1_0_1_0	-1.394 (0.000)***	0.137 (0.013)**
s1_0_1_1	-0.595 (0.203)	0.113 (0.030)**
s1_1_0_0	-0.771 (0.072)*	0.134 (0.010)***
s1_1_0_1	-0.264 (0.649)	0.087 (0.135)
s1_1_1_0	0.825 (0.013)**	0.125 (0.009)***
s1_1_1_1	-1.080 (0.001)***	0.150 (0.003)***
Mill's ratio	0.005 (0.838)	

Notes: Sample size: 551. *, ** and *** denote significance at the levels of 10%, 5% and 1%. *P*-values are i parentheses.

First of all, we note that the 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 in 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, market 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). On the contrary, the perception of knowledge obstacles is negatively associated with the innovative performance. Firm size affects the propensity to innovate positively and the innovative performance negatively. Foreign ownership matters for the capacity of firms to innovate, but not for the commercial success of innovation.

Turning to the organizational practices, the results differ for the two phases of the innovation process. Business practices, knowledge management and workplace organization, when separately adopted, have a significant negative impact on the propensity to innovate, while there is evidence of a significant positive impact of these practices on innovative performance. Combinations of different practices lead to negative effects on the propensity to innovate while there are positive effects of such combinations on innovative performance. Indeed, the joint implementation of workplace organization and external relations is negatively associated with the propensity to innovate but positively associated with the innovative performance. Although these results give some indications of the effects of different combinations of organizational practices on innovation output, it is however important to note that the individual significance and signs of the coefficients do not by themselves provide information on complementarity or substitutability between different organizational practices.

Testing for complementarity involves testing linear inequality restrictions, and the joint distribution of several of these restrictions (Mohnen and Röller, 2005; Love and Roper, 2009b). In our case, assessing complementarity or substitutability between organizational practices requires the joint testing of four inequality constraints for each pair-wise comparison. The results of the supermodularity and submodularity tests are provided in Table 4. Similarly to Mohnen and Röller (2005), we 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.

Our test results differ according to whether the firm is in the first step of the innovation process (i.e. being innovative or not) or in a subsequent step (i.e. the innovative performance). As regards the propensity to innovate equation, there is significant evidence of substitutability between knowledge management and work organization (pair 2–3), knowledge management and external relations (pair 2–4) and workplace organization and

external relations (pair 3–4). This finding clearly suggests that these organizational practices are all jointly substitutable in determining whether a firm is innovative or not. In other words, the implementation of one of three practices should be sufficient to motivate a firm to innovate. There is clear evidence of complementarity between business practices and workplace organization (pair 1–3); firms combining business practices (i.e. business re-engineering, lean production or quality management) and workplace organization (i.e. decentralization and teamwork) should benefit more from flexibility, adaptability and organizational performance – which may lead to a higher firm capacity to introduce technological innovation. Finally, one can observe that there is an unclear indication of either complementarity or substitutability between business practices and knowledge management (pair 1–2) as both the supermodularity and the submodularity hypotheses are accepted. The test is also inconclusive for the combination of business practices and external relations (pair 1–4).

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
Propensity to innovate	Supermodularity	2.079 A	1.847 A	5.410 N	8.123 N	9.532 R	12.788 R
	Submodularity	2.294 A	8.756 R	5.779 N	1.070 A	1.718 A	3.354 A
Innovative performance	Supermodularity	1.887 A	4.975 N	0 A	12.742 R	5.361 N	0.905 A
	Submodularity	7.291 R	2.967 A	5.280 N	0.873 A	0.993 A	2.747 A

Notes: Practices 1 to 4 correspond respectively to business practices, knowledge management, workplace organization and external relations. The lower and the upper bounds of the test at the 10% level (see Kodde and Palm, 1986) are respectively 3.808 (degrees of freedom = 2) and 8.574 (df = 5). A the null hypothesis H_0 is accepted (if the test statistic is lower than the lower bound); R H_0 is rejected (if the test statistic is higher than the upper bound); N no conclusion (otherwise).

In terms of innovative performance, the results show a complementarity between business practices and knowledge management (pair 1–2). Recall that business practices and knowledge management, when adopted individually, have a significant and positive impact on innovative performance (Table 3). The test results confirm the positive role of these organizational practices by highlighting the importance of their joint implementation, which should pay off more in terms of innovative performance than when implemented separately. On the contrary, there is a substitutability relationship between knowledge management and workplace organization (pair 2–3), knowledge management and external relations (pair 2–4) and business practices and workplace organization (pair 1–3). In the case of the combination of workplace organization and external relations (pair 3–4), the test is inconclusive as it accepts all the complementarity and substitutability hypotheses.

Overall, our results strongly point out the fact that the effects of the pair-wise combination of practices are not the same according to the phases of the innovation process. While some pairs (such as 2–3 and 2–4) are substitutable across both dimensions of innovation, others (such as 1–3) display strong evidence of complementarity in the innovative performance and, at the same time, significant substitutability in the innovative performance. Pair 1–2 is shown to be complementary for innovative performance while displaying unclear evidence for propensity to innovate.

6. Conclusion

The objective of this paper was twofold. First, we tried to understand which factors influence the firm's decision to implement organizational innovation. Second, we wondered whether alternative organizational strategies are complements or substitutes. A two-step analysis was performed. The first one consisted of analysing 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 of being an innovator and the share of 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 undertakes any innovation at all. The empirical study was based on the firm-level data set drawn from the Luxembourgish Community Innovation Survey (CIS 2006). This study is one of only two (known to the authors), the other being Cozzarin and Percival (2006), that examines innovation within the context of complementary organizational strategies and innovation performance.

Regarding the factors that determine the implementation of innovation organizational, significant and positive coefficients are found regarding the acquisition of advanced machinery, equipment and software, which affects the four practices. The perception of market-related obstacles to innovation has a significant and negative impact on the adoption of organizational practices. Another interesting result is that the competition context in the firms' main market is likely to motivate 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 regarding complementarity, the results from the two approaches used are quite different. Thus, through the correlation approach, all the pair-wise

combinations of organizational practices are correlated, even when the exogenous variables are controlled. Through the performance approach, where a pair of organizational practices are considered as complements as these innovative strategies mutually reinforce each other – as an increase in the level of any of them increases the marginal profitability of the other (Milgrom and Roberts, 1990, 1995), significant pair-wise combinations are carried out. Thus, it is important to note that 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 favour of the impact of complementary asset management raising firms' 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 to 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 later 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.

Our paper is not exempt from some limitations. The main one relates to the specific economic structure of Luxembourg, where service firms are mostly big and established companies such as those in banking, while the manufacturing sector is composed mainly of SMEs. Our results, however, do not emphasize significant differences between the manufacturing and the service industries. Future research should therefore replicate this study in countries where the two sectors have similar features. Also, as argued by Armbruster et al. (2008), it would be interesting to compare the results with other large-scale surveys (e.g. NUTEK, DRUID, EPOC, INNFORM, COI) that use different measures both for organizational innovations and for technological innovation. Therefore, this present analysis represents only a small step along the path to achieving greater knowledge concerning the variety of innovation patterns and complementarities, especially between organizational and technological innovations. Much work remains ahead to understand fully the complementary

effects of different types of innovation. Moreover, it is now largely recognized that it is problematical to address econometric endogeneity issues and make statements about directions of causality with cross-sectional data that do not allow the determination of whether the same firms are innovative every year or what keeps firms innovative over time (Mairesse and Mohnen, 2010). Future research could address this gap by analysing the dynamic relationships between technological and non-technological innovations.

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 the firm 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 the firm 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 the firm introduced new knowledge management systems to use or exchange better information, knowledge, skills within the firm or to collect and interpret information from outside the firm, 0 otherwise
Workplace organization	Equal to 1 if the firm 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 the firm 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 by the total turnover in 2006
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 in the production's technologies and the services, on a Likert scale (0 to 3)
Product changes	Rapid change in the products and services, on a Likert scale (0 to 3)
Product substitute	The products of the firm can be easily replaced by the products of competitors, on a Likert scale (0 to 3)
Demand forecast	Evolution of the demand is difficult to forecast, on a Likert scale (0 to 3)
Obstacles to innovation	
Financial obstacles	Equal to 1 if the score of importance of at least one of the 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 the 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 the 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 the 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 not part of a group (reference); equal to 2 if part of a national enterprise group; equal to 3 if part of a European enterprise group; equal to 4 if part of an 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

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and innovation: An inverted-U relationship. Quarterly Journal of Economics 120, 701–728.

Aiken, M., J. Hage., 1971. The organic organization and innovation. Sociology 5, 63–82.

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

Arora A., Gambardella, A., 1990. Complementarity and external linkages: The strategies of the large firms in biotechnology. Journal of Industrial Economics 38(4), 362–379.

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

Audretsch, D.B., Menkveld, A.J., Thurik, A.R., 1996. The decision between internal and external R&D. Journal of Institutional and Theoretical Economics 152, 517–530.

Becker, S.W., Whisler T.L., 1967. The innovative organization: A selective view of current theory and research. Journal of Business 40, 462–469.

Belderbos, R., Carree, M., Lokshin, B., 2006. Complementarity in R&D cooperation strategies. Review of Industrial Organization 28, 401–426.

Beneito, P., 2006. The innovative performance of in-house and contracted R&D in terms of patents and utility models. Research Policy 35(4), 502–517.

Black, S.E., Lynch, L.M., 2005. Measuring organizational capital in the new economy. In Measuring Capital in the New Economy. Carol, C., Haltiwanger, J., Sichel, D. (eds.). University of Chicago Press.

Bresnahan, T.F., Brynjolfsson, E., Hitt, L.M., 2002. Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. The Quarterly Journal of Economics 117(1), 339–376.

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

Carree, M., Lokshin, B., Belderbos, R., 2010. A note on testing for complementarity and substitutability in the case of multiple practices. Journal of Productivity Analysis DOI: 10.1007/s11123-010-0189-8.

Cassiman B., Veugelers R., 2002. R&D co-operation and spillovers: Some empirical evidence from Belgium. American Economic Review 92(4), 1169–1184.

Cassiman, B., Veugelers, R., 2006. In search of complementarity in innovation strategy: Internal R&D, cooperation in R&D and external technology acquisition. Management Science 52(1), 68–82.

Catozzella, A., Vivarelli, M., 2007. Beyond the knowledge production function: The role of R&D in a multi-faceted innovation process. Jena Economic Research Papers in Economics, 007-087.
Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Research Policy 35(8), 1166–1199.
Cozzarin, B.P., Percival, J.C., 2006. Complementarities between organisational strategies and innovation. Economics of Innovation and New Technology 15(3), 195–217.
Crépon, B., Duguet, M., Mairesse, J., 1998. Research and development, innovation and productivity: An econometric analysis at the firm level. Economics of Innovation and New Technology 7(2), 115–158.
Cummings, T.G., Srivastva, S., 1977. Management of Work: A Socio-Technical Systems Approach. Kent, OH: Kent State University Press.
Daft R.L., 1978. A dual-core model of organizational innovation. The Academy of Management Journal 21(2), 193–210.
Damanpour, F., Evan, W.M., 1984. Organizational innovation and performance: The problem of "organizational lag". Administrative Science Quarterly 29, 392–409.
Dixit, A.K., Stiglitz, J.E., 1977. Monopolistic competition and optimum product diversity. American Economic Review 67, 297–308.
Dougherty, D., 1992. A practice-centered model of organizational renewal through product innovation. Strategic Management Journal 23, 77–92.
Ettlie, J.E., 1988. Taking Charge of Manufacturing. San Francisco, CA: Jossey-Bass.
European Commission, 1997. Green paper. http://europa.eu.int/comm/employment_social/.
Evangelista, R., Vezzani, A., 2010. The economic impact of technological and organizational innovations. A firm-level analysis. Research Policy 39, 1253–1263.
Galia, F., Legros, D., 2004. Complementarities between obstacles to innovation: Evidence from France. Research Policy (33), 1185–1199.
Gallouj, F., Weinstein, O., 1997. Innovation in services. Research Policy 26, 537–556.
Gomez, J., Vargas, P., 2009. The effect of financial constraints, absorptive capacity and complementarities on the adoption of multiple process technologies. Research Policy 38, 106–119.
Grant, R.M., 1996. Toward a knowledge-base theory of the firm. Strategic Management Journal 17, 109–122.
Greenan, N., Guellec, D., Broussaudier, G., Miotti, L., 1993. Innovation Organisationnelle, Dynamique Technologique et Performance des Entreprises. INSEE Working Paper, No. G 9304.
Grilliches, Z., Mairesse, J., 1984. Productivity and R&D at the firm level. In R&D, Patents and Productivity. Grilliches, Z. (ed.). Chicago Press.
Henderson, R., Clark, K., 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly 35, 9–30.
Ichniowski, C., Shaw, K., Prennushi, G., 1997. The effects of human resource management practices on productivity: A study of steel finishing lines. American Economic Review 87(3), 291–313.
Jacquemin, A., 1988. Cooperative agreements in R&D and Europe antitrust policy. European Economic Review 32, 551–560.
Kimberley, J.R., Evanisko, M., 1981. Organizational innovation: The influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations. Academy of Management Journal 24, 679–713.

Knight, K.E., 1967. A descriptive model of the intra-firm innovation process. The Journal of Business 40, 478–496.
Kodde, D.A., Palm, F.C., 1986. Wald criteria for jointly testing equality and inequality restrictions. Econometrica 54, 1243–1248.
Kogut, B., 1988. Joint ventures: Theoretical and empirical perspectives. Strategic Management Journal 9, 319–332.
Kogut, B., Zander, U., 1993. Knowledge of the firm and the evolutionary theory of the multinational corporation. Journal of International Business Studies 24(4), 625–645.
Leiponen, A., 2005. Skills and innovation. International Journal of Industrial Organization 23(5–6), 303–323.
Lhuillery, S., 2000. The organizational practices of innovation and the performances of firms: An empirical investigation. Dynacom Series Working Paper, D19, LEM, Sant'Anna School of Advanced Studies.
Lokshin, B., Belderbos, R., Carree, M., 2008a. The productivity effects of internal and external R&D. Evidence from a dynamic panel data model. Oxford Bulletin of Economics and Statistics 70(3), 399–413.
Lokshin, B., van Gils, A., Bauer, E., 2008b. Crafting Firm Competencies to Improve Innovative Performance. UNU-MERIT WP 009.
Love, J.H., Mansury M.A., 2007. External linkages, R&D and innovation performance in US business services. Industry and Innovation 14(5), 477–496.
Love, J.H., Roper, S., 2001. Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants. Research Policy 30(4), 643–661.
Love, J.H. Roper, S., 2009a. Organizing the innovation process: Complementarities in innovation networking. Industry and Innovation 16(3), 273–290.
Love, J.H., Roper, S., 2009b. Organizing innovation: Complementarities between cross-functional teams. Technovation 29, 192–203.
Lynch, L.M., 2007. The adoption and diffusion of organizational innovation: Evidence for the U.S. economy. IZA DP No. 2819
Mairesse, J., Mohnen, P., 2002. Accounting for innovation and measuring innovativeness: An illustrative framework and an application. The Economics of Technology and Innovation 92(2), 226–230.
Mairesse, J., Mohnen, P., 2010. Using Innovations Surveys for Econometric Analysis. NBER Working Papers 15857, National Bureau of Economic Research, Inc.
Milgrom, P., Roberts, J., 1990. The economics of modern manufacturing: Technology, strategy and organization. American Economic Review 80(3), 511–28.
Milgrom, P., Roberts, J., 1995. Complementarities and fit: Strategy, structure and organizational change in manufacturing. Journal of Accounting and Economics 19, 179–208.
Miravete, E.J., Pernias, J.C., 2006. Innovation complementarity and scale of production. The Journal of Industrial Economics LIV, 1–29.
Mohnen, P., Röller, L., 2005. Complementarities in innovation policy. European Economic Review 49, 1431–1450.
Mohr, L.B., 1969. Determinants of innovation in organizations. American Political Science Review 63, 111–126.
Nelson, R.R., Winter, S.G., 1982. An Evolutionary Theory of Economic Change. Cambridge, Mass: Bellknap.
Nickell, S., Daphne, N., Patterson, M., 2001. Does doing badly encourage management innovation? Oxford Bulletin of Economics and Statistics 63, 5–28.

OECD, 2005. The Measurement of Scientific and Technological Activities – Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. Paris: OECD Publishing.

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

Pil, F., MacDuffie, J.P., 1996. The adoption of high involvement work practices. Industrial Relations 35(3), 423–455.

Prahalad, C.K., Hamel, G., 1990. The core competence of the corporation. Harvard Business Review 68(3), 79–91.

Rivkin, J.W., 2000. Imitation of complex strategies. Management Science 46(6), 824–844.

Sakakibara, M., 1997. Heterogeneity of firm capabilities and co-operative research and development: An empirical examination of motives. Strategic Management Journal 18(6), 143–16.

Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Research Policy 37, 1492–1503.

Schmutzler, A., 2007. The Relation between Competition and Innovation – Why Is It Such a Mess? Socioeconomic Institute, University of Zürich, Working Paper No. 0716.

Spicer, D.P., Sadler-Smith, E., 2006. Organizational learning in smaller manufacturing firms. International Small Business Journal 24(2), 133–158.

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

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

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

Tether, B.S., Tajar, A., 2008. The organisational-cooperation mode of innovation and its prominence amongst European service firms. Research Policy 37, 720–739.

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

Wernerfelt, B., 1984. A resource-based view of the firm. Strategic Management Journal 5(2), 171–180.

CEPS
INSTEAD

3, avenue de la Fonte
L-4364 Esch-sur-Alzette
Tél.: +352 58.58.55-801
www.ceps.lu