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THE FATEFUL TRIANGLE

COMPLEMENTARITIES BETWEEN PRODUCT, PROCESS AND ORGANIZATIONAL INNOVATION IN THE UK AND FRANCE

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Abstract:
This paper explores the triangle of relationships among product, process and organizational innovation, examining the complementarities and substitutes between these forms of innovation. Drawing from a large pooled sample of French and UK manufacturing firms, it investigates if firms can find a beneficial interplay between forms of innovation. A first analysis through a trivariate probit and a multinomial logit shows that the determinants of the different forms of innovation are not identical and the correlation of residuals in the trivariate probit displays national differences for the complementarities in use. The results of the tests of the complementarities in performance show that the efficient strategies of innovation combinations are not the same for all the firms. They depend on the national context as well as on the firm size and the firm capabilities, and give credit to the contingency hypothesis rather than to the naïve view of a unique best strategy. The main combinations are the "technological strategy" (product-process innovations) and the "structure oriented strategy" (organization-product), and in no case the combination of the three strategies at the same time, which is presumably too costly or difficult.

Keywords: Innovation, Organization, Complementarities, UK, France

JEL codes : C12, D24, L25, O31

1. **Introduction**

This paper explores the relationship between product, process and organizational innovation in order to better understand the complementarities between different forms of innovation. Since Milgrom and Roberts's (1990, 1995) seminal contributions, there has been a surge of research interest in complementarities in economics and management. This literature explores when sum is more than its parts, examining the beneficial interplay between different parts of a system (Athey & Stern, 1998). The complementarities perspective is not itself a theory of organizational design or performance, but rather an approach to help researchers to understand relational phenomena and how the relationships between parts of system create more value than individual elements of the system (Ennen & Richter, 2010). This approach helps to enrich understanding of how different practices and strategies are combined and recombined, and how such combinations shape subsequent performance.

The growth in complementarities research has been reflected in the study of innovation, where there has been a range of studies of complementarities between different forms of innovation and the managerial practices associated with innovation (Laursen & Foss, 2003; Leiponen, 2005; Martínez-Ros & Labeaga, 2009; Mohnen & Roller, 2005; Roper, Du, & Love, 2008). This work has demonstrated strong links between the forms of innovation as well as the relationship between internal and external knowledge in the innovation process (Arora & Gambardella, 1990; Cassiman & Veugelers, 2006; Mowery, 1983). Complementarities research has followed two broad approaches in its attempt to measure and understand complementarities, which we term, *complementarities-in-use* and *complementarities-in-performance*. The first – *complementarities-in-use* - may arise from the fact that two sets of activities are linked, in that the use of one practice often requires the use of other practices. In this case, there is a strong fit between practices, suggesting a mutual and beneficial interaction between different practices. In this approach, researchers have sought to identify the relatedness in the use of different practices, finding evidence that some practices are usually combined with others (see for example Colombo, Grilli, & Piva, 2006; Galia & Legros 2004). The second approach - *complementarities-in-performance* - explores the performance effects of the use of different practices in combination with one another. These studies offer a direct test of the economic value to the firm in fitting together different activities or practices and how the mutual product of the joint use of these practices produce economic benefits that are greater than the individual parts. In this paper, we seek to advance knowledge of both of these different forms of complementarities as they concern product, process and managerial innovations.

Although the literature on innovation has begun to uncover the rich and deep complementarities between product and process innovation, it has just started to unearth the effect of other forms of innovation. In this paper, we focus on a triangle of relationships between three forms of innovation: product, process and organization. By focusing on organizational innovations, we are able to overcome the strong pro-technology bias that pervades much of the literature on innovation (Edgerton, 1999) and to see how innovations that involve the creation of new forms of organization, novel ways of selling products and mechanisms for exchanging knowledge within the firm can act as complements and substitutes for more traditional technology-based innovation forms (see also Mol & Birkinshaw, 2009).

The paper is based on an analysis of the UK and French Innovation Surveys for 2005. By pooling these two samples and analyzing them individually, we are able to explore how the complementarities vary across countries. In doing so, we can determine what relationships are specific to national contexts. Our analysis proceeds in two stages. First, using trivariate probit and multinomial regressions, we analyze the factors that lead to the presence of each form of innovation within the firm and the factors that lead the firm to combine different forms of innovation. Second, using a Heckman selection procedure on innovative firms, we explore the effects on labour productivity of the presence of different combinations of three forms of innovation, applying direct sets of strict complementarity. We explore the results of these regressions for the pooled sample as well as for France and UK.

The results tend to show that organizational and product innovations are complements when firms don't use process innovation. In other words, it is better to introduce at the same time organizational and product innovation when firms don't use process innovation. Product and process innovation are found to be complements when organizational innovation is absent. We find also some substitution effects, especially between organizational and process innovation in the case where firms use product innovation. In that case, using organizational or process innovation allows reaching the same performance effect.

Comparing France and UK, we found similar results concerning complementarities, but no complementarities effects between organizational and product innovation in UK. However, we do not find any specific substitution effect in both countries.

Complementarities depend on the resources and capabilities of the firm. For high-tech firms, we find complementarities between organization and product innovation, no matter of the introduction or not of process innovation. We find also that product and process are complements when organizational innovation is not introduced. The weaker the firm’s capabilities, the more substitutes there are especially between product and process when organizational innovation is absent.

2. Complementarities in economics and management literatures and innovation

2.1. Complementarities among practices

R&D has been for a long time considered as the driving factor of innovation (Mairesse & Mohnen, 2005). However the literature on firm production and performance as well as on innovation has started introducing intangible factors such as human capital. But this extension of independent production factors is not enough. The Japanese success story appears as a mystery if one looks just for the addition of independent factors. Clearly the organisation of the firms and perhaps the organisation of the economic and social system are key factors. The idea is that the sum is more than the parts, and that factors are complementary. Factors are Edgeworth complements if doing more of any one of them increases the returns to doing more of the others.

This idea has received a wide audience since Milgrom and Roberts (1990) proposed to use mathematical tools new in economics to develop models of this Edgeworth complementarity, and applied them to the explanation of some major phenomena. Milgrom and Roberts (1995) propose a simple model to explain the move from the fordist (mass production) firm to the “modern” lean, flexible firm. Complementary factors mean that a very different set of values in the main characteristics (for instance high pay replacing low pay) or often a discrete change in many characteristics (for instance the introduction of a new pay system) are necessary for the efficiency of the modern firm. Some external change such as the fall of the cost of the flexible manufacturing equipment or the availability of Computer-aided design for new products may bring about a complete change in the organisation of the firm. They go on to apply the story told by the model to the more informal analysis of the Japanese economic system and the explanation of the long-term competitive advantage of Lincoln Electric. Organizational coherence is at the heart of the benefits of complementarity, but it is also important to stress the source of lasting competitive advantage that a more complex strategy gives to a firm since it acts as a barrier to organizational imitation, as proved theoretically by Rivkin (2000).

A major problem with the analysis of complementarities in a performance function for empirical analysis was the need for the divisibility of the choice variables and the smoothness of the objective function (Ennen & Richter, 2010). This was a major obstacle for considering changes in organisation, which are often discrete. An example is the use of fixed salary versus a flexible pay based on performance. Milgrom and Roberts show that the use of lattice theory (Topkis, 1978) requires only the possibility of ordering: doing more than one thing increases the returns to doing more of another. Smoothness and concavity are not necessary. In the simplest case in which two factors x and y take two values, 0 and 1, the complementarities are expressed by the following conditions on the objective function f(x, y):

$$f(1,1) - f(1,0) > f(0,1) - f(0,0)$$

Such a function is said strictly supermodular in x and y.

This framework is now applied to find complementarities in the range of different settings, including human resource management, strategy, resources, knowledge management, advanced manufacturing technology (see Ennen & Richter, 2010 for a summary of this literature). The incidence of complementarities between different practices seems strongly dependent upon the method of analysis as those studies that look interactions between elements have a lower likelihood of finding complementarities than studies that focus on systemic relationships (Ennen & Richter, 2010). This overall finding suggests that determining the presence of complementarities is strongly determined by the boundary conditions of a study. Choosing the set of practices to be investigated is a significant challenge as an omitted practice from a study may lead to misleading conclusions about the efficacy of a combination as the benefits of that combination may only be realized when they are combined with a third or even fourth unmeasured element. This indicates that an important part of the research agenda for understanding complementarities should be to look at *multiple* elements rather simple interactions, allowing researchers to understand beneficial interplay arising from systems of relationships.

The complementarities literature also addresses the extent to which practices may act as substitute for one another or whether the use of different sets of practices may lower overall performance. This is the dark side of complementarities, as it indicates that in some cases mutual adoption of practices may lower performance. This research suggests use of some sets of practices in combination may induce failure. Several reasons are offered in the literature for this negative outcome. First, the set of practices being undertaken by the firm may be incompatible. For example, research on goal-directed behavior has suggested that the use of strong financial performance rewards may crowd out intrinsic motivations (Ordonez, Schweitzer, Galinsky, & Bazerman, 2009). Other research on managerial strategy indicates that firms struggle to find the balance between exploration and exploitation (March, 1991). The organizational mechanisms that support exploration may be antithetical to those that support exploitation (Tushman & O'Reilly, 1997). Second, developing a broad set of managerial practices in a short period may stretch the organization, diluting the managerial time and attention (Ocassio, 1997), and increasing costs. Managerial resources may be dissipated in these attempts to develop and manage a wide range of tasks, lowering overall performance. Laursen and Salter (2006) find evidence for this allocation attention problem when looking at implications of firms' external search activities on their innovative performance.

Rarely, however, do managerial practices operate in clearly demarked domains, such as external and internal R&D, and some managerial concepts are themselves symbols for a range of different but overlapping sets of practices. For example, the term 'knowledge management' has been used to refer to a broad range of practices, including intranets, expert yellow pages, capturing lessons from past projects, and staff rotation and mentoring programs (Argote, McEvily, & Reagans, 2003). Research has shown that these knowledge management practices tend to be clustered within a firm, as they reflect a set of managerial practices towards the organization of practices around the nature of knowledge within the firm (Gault & Foray, 2003). Moreover, the set of practices included within a domain of managerial practice is often unclear and may evolve over time. This lack of clarity may reflect ambiguity in the set of managerial practices associated with a particular meta-practice, such as knowledge management. Such ambiguity may be related to the challenge of delimiting the set of practices that are useful within the larger operating set of a wider *meta-practice* or *meta-routine* (Nelson & Winter, 1982). Indeed, business consultants are usually paid handsomely for helping firms figure out what set of practices are critical to larger a meta-practice. The ambiguity may also arise out of a lack of understanding of the causal mechanisms that underpin a set of managerial activities and their performance outcomes (Lippman & Rumelt, 1982). Such causal ambiguity can only be resolved through experimentation within the firm with different practices, and learning about best different practices can be needed to make them work together successfully.

Moreover, the complements between different sets of practices are not static. An example of this evolution in a complementary set of practices can be seen in the use of 'lean production' or 'lean thinking', a group of managerial ideas that emerged out of studies of the manufacturing excellence of Japanese automotive companies, especially Toyota. At first, the literature on lean production suggested the practices were critical enabling ‘lean manufacturing’, including measurement of waste, workflows and process steps and inventory management (Womack, Jones, & Roos, 1991; Womack & Jones, 1996). However, as these ideas have evolved through their use in practice, they have become broader, covering a wide range of managerial efforts outside the narrow confines of manufacturing where they first developed. Now, these ideas cover a set of practices around ‘lean thinking’ that can be applied to environments far removed from the manufacturing process where they first evolved (Womack & Jones, 2005).

In summary, both case of knowledge management and lean production suggest that *complementarities-in-use* are common place and that a set of mutually reinforcing requirements and managerial practices may led to sets of activities to be undertaken concurrently in order to realize the benefits of one activity with another.

Although this literature documents the mutual presence of different practices, it often does not address the performance implications of the combined use of different practices. It may be performance benefits of one practice can only be realized when used in combination with other practices. Attempts to capture the performance benefits associated with complementarities have focused on estimating production functions.

2.2. Complementarities among forms of innovation

Since Schumpeter, it has been widely acknowledged that there are strong complementarities between forms of innovation. Indeed, innovation scholars often commented that radical innovations often led to changes in product markets as well as processes of production (Freeman & Soete, 1997; Utterback, 1994). Moreover, such innovations may also beget changes in marketing, delivery and geographic scope of a set of production or service activities. This broad character of innovation suggests that studies that focus on single forms of innovation – product, process or organization – may miss out important relationships between these different forms of innovation. Indeed, it may be that to gain from an innovation, it is necessary to transform other parts of the firm’s innovation efforts, including changing the system of production or delivery and organizational structure that supports the innovation. The importance of different forms of innovation is also reflected in Teece’s (1986) profiting from innovation framework, which emphasizes the returns to innovation usually go to those organizations that hold valuable and rare complementary assets. These complementary assets amplify the original value of the innovation for the firms holding such assets, indicating complementarities between the innovation and other assets classes or activities of the firm.

In the literature on innovation, particular attention has been placed on the potential complementarity on the relationship between internal R&D and external knowledge. When examining the rise of industrial R&D and R&D services in the US in the early 20th century, Mowery (1983) found there was a strong complementarities relationship between internal and external R&D investments. Arora and Gambardella (1990) also found evidence for the existence of complementarity between internal and external R&D investments, when studying the large firms in biotechnology. Along these lines, Cassiman and Veugelers (2006) test the complementarity between two factors, internal R&D and external knowledge acquisition, on a sample of 269 Belgian firms. They find complementarity, but push the analysis further to show that this complementarity has a stronger effect on performance when the sample is reduced to firms having a higher basic R&D reliance, i.e. getting more information from research institutes and universities than on suppliers and customers. Belderbos, Carree and Lokshin (2006) study the performance effects of simultaneous engagement in R&D cooperation with different partners (competitors, clients, suppliers, and universities). The results suggest that the joint adoption of different R&D cooperation types can have inverse effects, depending on the specific strategy combinations and on firm size; Small firms may face diseconomies of scale when pursuing many strategies, which are costly to manage.

One of the most commonly documented complementarities in the study of innovation has been the link between product and process innovation. A range of studies have found complementarities-in-use between product and process innovation (Martínez-Ros & Labeaga, 2009).

These studies demonstrate that new products may require changes in processes in production and vice-versa. Using a study of 56 firms in German metal working, Kraft (1990) demonstrated that product innovation might explain the presence of process innovation, but the process innovation did not predict product innovation. Building on this work and exploring the case of Spanish manufacturers, Martinez-Ros (2000) found that product innovators were 36% more likely to be process innovations. Looking at a sample of UK manufacturing firms, Reichstein and Salter (2006) found that the overlap between the two forms of innovation was greatest when the level of novelty of the innovations was high. Along these lines, Miravete and Pernias (2006) tested the existence of complementarity between product, process innovation and the scale of production (measured by output) on a Spanish set of 432 firms in the ceramic tile industry. Their conclusion is that the significant association between product and process innovation is mostly due to unobserved heterogeneity.

Corrazin and Percival (2006) are among the first to study the complementarities between the organizational strategies and innovation with the supermodularity methods. Their data set covers 5,944 Canadian firms in 1999 and explores sixteen possible factors of innovation. This method prevents them from studying such a large number of factors since the number of pair-wise comparisons rises very quickly. Therefore, they aggregate these sixteen factors by principal component analysis into four factors, which they term: hiring focus, R&D focus, market focus, and reputation focus and then estimate separately the model for each industry. Complete supermodularity does not occur, but pair-wise complementarities are frequent, yet concern factors that are different among industries. Percival and Corrazin (2008) extended this analysis, distinguishing between three levels of innovation intensity, firm level, Canada level, and world level, and partition the sample by industry. Then they compute the proportion of pair wise complements and substitutes and compare them between the different intensities of innovation and industries. No simple result appears, yet it occurs that low-tech firms may have as frequent complementarities as high-tech firms, as opposed to what could be expected. One problem with the use of the principal component analysis to reduce the number of factors is that the content of factors changes from one paper to another and the identity of each factor is not stable.

Most studies of complementarities have focused on single countries and this is a significant limitation. However, Mohnen and Röller (2005) study attempts to examine the factors that affect innovation for four countries, with data from CIS1 for 1992 at firm level. They consider four obstacles to innovation, factors relating to risk and finance, factors relating to knowledge-skill within the enterprise, factors measuring the knowledge-skill outside the enterprise, and regulation. The results suggest a number of complementarities between pairs of obstacles with the probability of becoming an innovator as the objective function, while there is more substitutability when the objective function is the intensity of innovation.

The role of skills as complement to innovation and R&D collaboration in a profit margin objective function has been investigated by Leiponen (2005), using a panel of 159 Finnish firms. The results give support to strict supermodularity between skills and R&D collaboration. However, the results are not so neat when interaction between skills and innovation is considered. When distinguishing product and process innovation, strict supermodularity of technical skills and product innovation is obtained, and the same result applies with technical skills and process innovation. The sample is too small to study the interaction of the two forms of innovation in order to extend the analysis.

Although these studies of the complementarities between product and process innovation have deepened our understanding of the beneficial interplay of different forms of innovation, they have a strong pro-technology bias in that they focus on innovations that involve narrowly defined technological newness. As Schumpeter originally suggested, innovations often require significant changes in the organization and management in order to be successful delivered to the market. In order to better stand these factors; researchers have increasingly been focused on the sources and determinants of managerial or organizational innovations and their impact on performance. In this sense, it is important to go beyond the role of the *leve*l of skills in innovation to consider the *change* in skills and more generally the *changes* in management on technological innovation or in interaction with it.

In 2001, several European countries added new question to the CIS to capture the 'wider innovation' activities of the firms. These questions attempted to capture changes in the firm's managerial activities, including four items related to changes in the organization's structure, marketing efforts, strategy and system for managing knowledge. These questions are often referred to by researchers and governments as 'non-technological' innovation, drawing on the distinction in the 2^{nd} edition of Oslo Manual between technology and non-technological innovation (OECD, 1997). However, the literature exploring the sources and determinants of these forms of innovation is shorter and more recent. Schmidt and Rammer (2007) use the German CIS4 survey to look at 'non-technological innovation'. This version of CIS contains information on profit margins. They do not test for supermodularity, but in a first part of their study use bivariate probits to compare the determinants of technological and non-technological innovations and find them similar. They also show that the two forms of innovations are linked to each other, although not systematically. In a second part of their analysis, they demonstrate, using ordered probit and tobit techniques that sales are higher for firms which combine product and process innovation with both marketing and organisational innovation. The profit margin is higher for the sole combination of organisational and product innovation.

Building on this approach, Mol and Birkinshaw (2009) is one the rare papers to investigate management innovation or 'non-technological' innovation directly. Using CIS3 for UK, they explain the firm performance, measured by productivity growth, by the introduction of new management practices and find it highly significant. The dummies for product and process innovation are not significant. They also use an ordered logit to explain the number of new management practices introduced, and it reveals the influence of size, education, the use of internal and market sources, but also product and process innovation. Finally, Polder, Leeuwen, Mohnen and Raymond (2009) go further with a three-step model in the CDM framework. They first explain R&D and ICT then use a trivariate probit to explain product, process and organizational innovation by R&D and ICT. These three innovations feed in the production function, which corresponds to Total Factor Productivity. The model is estimated on Dutch firms data and one of the most important results is that only organizational innovation alone leads to higher TFP level, while product and process innovation only lead to a higher TFP when performed together with an organisational innovation. However they do not test complementarities through the exclusion inequalities.

Drawing on this emerging research stream, we explore the triangle of relationships among product, process and organizational innovations. In doing so, we are able to look at how multiple elements of innovation may jointly shape economic outcomes. By doing so, it should be possible to gain a deeper appreciation of how the value from innovations is developed and how combinations of innovations may yield economic value. In addition, unlike past most studies of complementarities in innovation, we focus on two different countries. In particular, we pool data from the French and UK 2005 Innovation Surveys, based on the wider Community Innovation Survey, to examine the relationships between the three different forms of innovation. We use this approach to ensure that evidence of complementarities is tied to specific national contexts. In this sense, we want to see what complements (or substitutes) are invariant across national contexts. A France-UK comparison is particularly useful in this respect as the two countries; although geographically proximate differ so markedly in their national business and innovation systems. This comparison should allow us to start to better understand how complementarities are determined by national factors, expanding the scope and nature of research on complementarities outside its current national specific focus (see also Mohnen and Roller, 2005 for a cross-country study of complementarities).

3. Data, econometric methodology, and variables description

3.1. Data

For this study, we combine information from the 4th Community Innovation Survey (CIS) for France and the UK. CIS data is based on firm-level surveys that ask organizations to provide on their level and form of innovative efforts. Although definitions of innovation and examples are provided to respondents, all the information relies on self-reported information by managers within these organizations and therefore it has a strong subjective element (OECD, 2005). The data has the advantage of being *comprehensive*, as it covers all sectors of the private economy and *detailed*, as it captures information on many different aspects of firm's innovative efforts. Overtime, it has become a central tool for researchers working on understanding the innovation process, and there have been over 100 papers publishing academic journals using the data, including leading economic and management journals (see Smith, 2005).

Increasingly, researchers have sought to combine CIS data from different countries and waves of the survey to better understand whether findings from the earlier generation of single country, cross-sectional studies are valid (Griffith, Heurgo, Mairesse, & Peters, 2006; Lööf & Heshmati, 2003). However, combining CIS data across countries can raise significant challenges. Although in theory, CIS data is based on a harmonized questionnaire and common sampling strategy, there are significant national differences in the forms of questions asked, the phrasing of the questions and the construction of the samples. In part, these differences are due to national statistical offices and governments requirements and interests, and the fact that the EU regulation concerning CIS data does not specify exactly the information required to be provided by the Member-States to Eurostat, the EU's official statistical agency. Moreover, it is difficult for researchers to combine CIS data between countries due to restrictions of use on the data within individual-level countries. An attempt to create cross-country data within Eurostat has required that the data be micro-aggregated, leading to the averaging of scores for individual firms into general pools. Although this micro-aggregated data has been used successfully in several studies (see Mohnen & Roller, 2005), it does not contain the same richness as the national-level data. In this study, we use the basic data from UK-France CIS 4 since later versions of the CIS in the UK are not made available directly to researchers and therefore it is very difficult to undertake this analysis.

The 2005 UK Innovation Survey was implemented by Office of National Statistics in April 2005 and sent to XX firms. Although voluntary, it received XX responses, a response rate of XX percent. The sample was based on census of firms with over 250 employees and a stratified sample of firms of small and medium sized firms. It covers only firms with over 10 employees. Overall, the patterns of responses closely mirrored the original population in terms of size, sector and regional distribution.

The 4th Community Innovation Survey in France was carried out by SESSI (Ministry of Economics, Finances and Industry) in 2005, covering the 2002-2004 period. Like UK survey, it focuses on firms with over 10 employees, a stratified sample of firms under 250 employees and census of large firms. The survey population included 25,000 firms, drawn manufacturing, services and construction sectors. Unlike in the UK, it was a mandatory survey and it received a response rate of 86 percent, including 8,438 firms from manufacturing sector. As expected with such high a response rate, the sample closely mirrored the original population.

There are important differences between the samples for these two surveys. On the French survey, non-innovators were not asked to report information on many aspects of their innovative activities, whereas in the UK all firms were asked to report on their innovative activities, whether or not they innovated in the period of the survey. In order to harmonize the two sets of data, we removed responses from firms in the UK sample that did not meet the French sample criteria, and we focus on manufacturing alone to improve comparability. This exclusion restriction reduced the UK sample from 16445 to 3627 firms.

Adopting this sample construction approach and merging the two datasets, we are left with 9318 firms, with 3627 for the UK and 5691 for France. In general, French firms are larger, more R&D intensive, and more innovative than the UK organizations. However, since our attention is focused on individual firms and performance consequences of different forms of innovation, we do not attempt to explore the reasons for these national differences.

3.2. Methodology

Our approach to investigate complementarities among the forms of innovation is based on two approaches: *complementarity-in-use* and *complementarity-in-performance*. We will consider the triangle of relationships among product, process and organizational innovation as binary variables (1 when a firm introduces the associated innovation, 0 otherwise). We also consider eight combinations of innovations defined from (0, 0, 0), when none of the three forms of innovation (product, process and organization) are introduced; to (1, 1, 1) where all the three forms of innovation are introduced together.

Testing complementarity- in-use

To address questions about the *complementarities-in-use* among product, process and organizational innovations, a first and naïve way is to look at the descriptive statistics on each combination of innovations introduced; and check the existence of firms corresponding to each combination. It is also necessary to control for some of the key variables that have been found to be likely to influence whether a firm introduces an innovation using a trivariate probit. Contrary to the use of three separate binary probit, the trivariate probit allows us to estimate simultaneously the three equations explaining the three non-exclusive forms of innovations. In this respect, we draw upon the 'standard package' of variables used to explain innovative forms in past studies, using CIS data. These variables include investments in R&D and training, size, innovation collaboration, technological and financial obstacles, use of formal and informal protection methods, as described below. As part of our analysis, we will show how these variables have different effects in explaining different innovation forms. Using these results from the trivariate probit, we adopt the 'correlation' approach to the measurement of complementarities (see Cassiman & Veugelers 2006). This approach consists in checking whether there is evidence for correlations among the residuals for each of the three different forms of innovations (product, process and organizational innovations) taking into account the key variables explaining innovations.

However, this trivariate probit approach only focuses on three different non-exclusive innovations forms - product, process and organizational innovation - and does not allow us to explore the factors that lead firms to develop different combinations of innovations. In order to clarify this issue, we use a multinomial logit with the same explanatory variables explaining each of the seven combinations of innovations, with none of the innovations as the reference case. To be more precise, we define by $W1_i1_j1_k$ a set of eight exclusive dummies that ranges from W000 to W111, where 1_i=1 if the firm introduces a product innovation; zero otherwise, 1_j=1 if the firm introduces a process innovation; zero otherwise and 1_k=1 if the firm introduces an organizational innovation; zero otherwise. In that case, W000 is related to the combination where none of the three innovations are introduced, W111 indicates that the firm is introducing all forms of innovation together, whereas W110 informs us that the firm is innovating in product and in process, but not in organization. This multinomial logit approach allows us to investigate in more details the firms' strategies concerning the combinations of innovation.

Testing complementarity- in-performance

In the second approach of this paper, we implement a supermodularity test in order to test for *complementarity-in-performance* between the three forms of innovations. We use a Heckman regression to explore the effects of each of the seven innovation combinations on labor productivity as a performance function. Our selection here is based on innovating firms (including those who tried to innovate) versus non innovating firms. We use labor productivity (sales per employee) as our measure of performance because it has been widely applied in past studies of the performance effects of innovation. It is readily available for both UK and French firms in the pooled sample (for a similar approach see Griffith et al., 2006).

Selection bias may occur because we are doing our subsequent estimations on the sub-sample composed of innovating firms (in product and/or process) or firms trying to innovate, and because the decision to be engaged in technological innovation cannot be considered as an exogenous phenomenon. The choice of this sub- sample comes from the absence of information on key explanatory variables for the firms who did not innovate or either tried to innovate in product or process. This may of course lead to some bias in our results. To control for such a selection bias, we will use a Heckman selection procedure when we estimate a performance equation.

The selection equation includes group membership (group), selling in international market (marint) and the three kinds of obstacles to innovation (financial, knowledge or marketing). This guarantees the exclusion restrictions. In all the specifications used, the Likelihood Ratio test (LR test) rejects the absence of selection problem. This justifies the use of the Heckman selection procedure.

The model we estimate is a linear one in which the dependant variable is a proxy for the firm performance. We have a common measure for labor productivity in France and UK, *ie* sales per employee (in log)[1]. This performance specification will then allow us to test for the complementarity between the three forms of innovation using the supermodularity approach.

To test for the supermodularity in each pair of innovations *ie* [product and process], [product and organization] and [process and organization], one needs to test for a pair of inequality restrictions. For example, if we want to test for the complementarity between product and process innovation, we have to test the two following restrictions constraints (*C1* when organizational innovation is absent and *C2* when organizational innovation is present) together:

C1 : W110 + W000 > W010 + W100
C2 : W111 + W001 > W011 + W101

H0:
W110+W000-W010-W100 > 0 (a) C1 (absence of organizational innovation)
W111+W001-W011-W101 > 0 (b) C2 (presence of organizational innovation)

H1:
W110+W000-W010-W100 = 0 (absence of organizational innovation)
W111+W001-W011-W101 = 0 (presence of organizational innovation)

If these two restrictions are simultaneously accepted, the performance is strongly (or strictly) supermodular in product and process. For reasons to be given below, we will in this paper use slightly different words, saying that product and process are *strong unconditional complements*. In other words, product and process complementarity occurs independently of the absence or presence of organizational innovation. We can also define *weak unconditional complements* when '>' is replaced by '≥'.

As we have also to test for *strong unconditional complementarities* for the two other pairwise of innovations forms, we have to test similarly:

for product and organizational innovation:

W101+ W000 > W100 + W001

[1] We have also information on valued added and total assets only for France, which allows us to estimate a production function (a translogarithmic specification allowing for more heterogeneity between firms).

W111 + W010 > W110 + W011

for process and organizational innovation:
W011 + W000 > W010 + W001
W111 + W100 > W110 + W101

Testing for *strong unconditional substitutability* between product and process innovation, we have to test the two following restrictions constraints (*C1s* when organizational innovation is absent and *C2s* when organizational innovation is present) together:
W110 + W000 < W010 + W100 (C1s: absence of organizational innovation)
W111 + W001 < W011 + W101 (C2s: presence of organizational innovation)

However in this paper we suggest a more detailed approach to complementarity than in the literature. We will also consider *conditional complementarity* which we define as complementarity between two forms of innovation conditional to the introduction or not of the third form of innovation. For example, testing conditional complementarity between product and process implies to test the complementarity in certain circumstances; *ie* conditional on the absence or presence of organizational innovation. This more detailed approach permit to explore deeper the complementarities and substituabilities between forms of innovation.

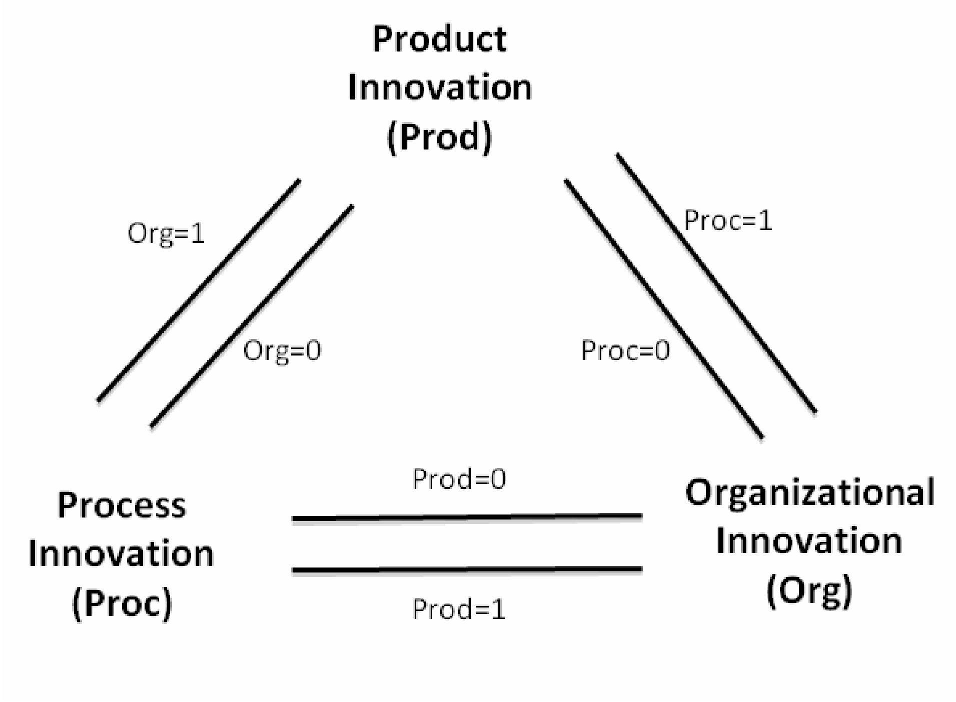
In that case, either of the following restrictions *C1* or *C2* must be accepted:
H0:
W110+W000-W010-W100 > 0 (a) *C1 (absence of organization innovation)*
H1:
W110+W000-W010-W100 = 0 (absence of organization innovation)

H0:
W111+W001-W011-W101 > 0 (b) *C2 (presence of organization innovation)*
H1:
W111+W001-W011-W101 = 0 (presence of organization innovation)

As we have also to test complementarities for each other pair of innovations forms, we have to test conditional complementarity between product and organizational innovation conditionally on the absence or presence of process innovation with the two tests detailed in Table 6.

Last, we have to test conditional complementarity between process and organizational innovation that implies to test the complementarity in certain circumstances; *ie* conditional on the absence or presence of product innovation with the two associated tests (see Table 6).

After all these tests of *unconditional* and *conditional complementarity* and *substitutability*, we are able to explore the following fateful triangle:



3.3. Variables description

In the first stage of the analysis (trivariate probit, multinomial logit), the dependent variables are whether or not a firm has innovated in each of three categories of innovation, whereas in the second stage (performance equation) these same variables are used as independent variables. Product innovation was taken from a question on both surveys to whether the firm had developed a product that was new for their market. The question defined product innovation as the market introduction of a new good or service or significantly improved good or service respective to its 'capabilities' (UK) or 'functionalities' (France). New-for-the-market innovation was defined in the UK as "your firm introduced a new good or service onto your market before your competitors", whereas in France the definition was the same, except for that it allowed for firms to declare their new-to-the-market innovations that were available in other markets as well.

Following the UK survey, process innovation was defined as the use of new or significantly improved methods for the production or supply of goods or services. In France, the question was phrased slightly more broadly to include techniques, technology and new knowledge leading to development of new processes or production methods and respondents were provided with a detailed list of activities pertaining to process innovation, with several examples. Although not providing examples, the UK question specifies that process innovation should exclude purely organizational or managerial changes, whereas in France no specific guidance is provided to respondents about the exclusion of organizational and managerial changes.

To measure organizational innovation, our approach builds on the techniques used by Schimdt and Rammer (2007) and Mol and Birkinshaw (2009). Organizational innovation was measured by using questions on the French and UK CIS about 'wider innovation' (UK) and 'organizational and marketing innovations' (France). In the UK questionnaire, wider innovation is taken to refer to "new or significantly amended forms of organization, business structures or practices, aimed at step changes in internal efficiency or effectiveness or in approaching markets and customers". Respondents are provided with four items, and for this study we used three of these items that corresponded with items on the French survey. These items include: 'implementation of advanced management techniques, e.g. knowledge management systems, Investors in People'; 'implementation of major changes to your organizational structure'; and 'implementation of changes in marketing concepts or strategies', with examples for each. In contrast, the French survey is more detailed in its treatment of organizational and marketing innovation, including nine items covering different aspects of this broad concept. In order to match the two surveys, we used four of the nine items to create three overlapping actions, which were: ‘a new or significantly improved system of knowledge management’; ‘important modifications of work organization within the firm’ and the combination of the items ‘significant modification design and packaging of goods or services’ and ‘new methods or significant modifications of sales or distribution methods’. If a firm indicates it undertakes any one of these three actions, it is defined as being an ‘organizational innovator’.

We used this broad measure of organizational innovation in order to ensure that the action was consistent with the approach used in the CIS for product and process innovation. In the survey, product and process innovation are also defined broadly and firms can declare that they have a single innovation in either of these categories over the three-year period. To ensure consistency, we adopt a similar approach for organizational innovation, allowing firms to be considered organizational innovators if they were able to achieve at least one of the three different actions. We also adopted this strategy for pragmatic reasons to help to ensure that we have a reasonable number of firms for each of our seven potential actions.

To be sure, the measurement of organizational innovation on the CIS begs many questions as it concerns only a few areas of managerial practice, makes no attempt to overlap with prior attempts to measure organizational or managerial innovation, and provides only the faintest hit of the rich organizational challenges of developing and delivering other forms of innovation. In this respect, it is poor and incomplete measure of what is a broad and rich concept (AMR paper). In part, this confusion is reflected in the 2nd version of the Oslo Manual (OECD, 1997) and in many policy documents, which refer to these forms of innovation as ‘non-technological innovation’, which is itself possibly misleading term as it defines something by what it is not rather than what it is. Much greater progress and attention will need to be placed on the measurement and conceptualization of this form of innovation, if a greater understanding of its sources and impacts on performance are to be realized in the future.

Our measure of labor productivity is based on the sales per employee in 2004, the last year covered by the survey. Although highly imperfect as a measure of performance, it has been used in many other studies of the performance effects of innovation using CIS data (Crépon, Duguet, & Mairesse, 1998; Griffith et al., 2006; Roper et al., 2008). Moreover, since our measure of labor productivity is taken during the same time as our innovation data, it raises difficult questions about the timing of the effects of innovation. It can be expected that the productivity benefits of an innovation may take several years to be translated into productivity gains. However, to enable a direct test of the effects of complementarities, it is requirement to have a clear performance variable and therefore we have used this measure to allow us to explore this question.

In order to explore sources of each type of innovation and critical factors that might explain innovativeness more generally, we have introduced a number of control variables into the model. First, as size is a critical variable in determining innovative outcomes (Cohen, 1995), we have controlled for firm size by using the share of full time equivalent staff. Second, since investments in R&D are often a precursor to innovative outcomes and they help firms more successful absorb knowledge from outside their firm, we have included a measure of R&D expenditures per FTE employee for each firm (Cohen & Levinthal, 1990). Third, investing in training is a signal that firms invest resources in improving the quality of their employees and therefore we have introduced a dummy variable indicating if the firm invested in training for innovation. Fourth, research has shown that firms that cooperate with external organizations are more likely to innovate and, given this, we have included a dummy to measure if the firm had a formal collaborative arrangement with an external organization (Ahuja, 2000; Tether, 2002). Fifth, as past research has found that firms open to external ideas were more likely to innovate and this openness variable also appears to explain management innovation, we have included a measure of openness (Laursen & Salter, 2004; Mol & Birkinshaw, 2009). To construct this measure, we have used the same approach as Laursen and Salter (2006), simply counting up the number of times a firms indicates it drew knowledge from ten possible sources of external knowledge, giving us a variable that has a value of between 0-10. Sixth, in the pursuit of innovation, firms can face many obstacles and past research has shown that how firms perceive these obstacles can shape their performance. In order to measure obstacles, we have used a measure of three different types of obstacles: financial, technological and market (Mohnen & Roller, 2005). This measure was constructed by creating three groups of two items from the question on the CIS about barriers to innovation. We assigned the firm 1 if it indicated that this type of obstacle was an 'important' and 'very important' barrier. Seventh, since the mechanisms firms use to protect their innovation may shape their ability to capture returns from these innovative efforts, we used two measures to capture firms appropriability strategies. The first of these measures the extent of use of formal methods of protection, such as patents, trademarks, design registrations and copyrights and the second covers informal methods, such as lead times, secrecy and complexity. Both measures involve coding the response of each firm for its use of each type of protection method, with 0-4 measure for formal methods and a 0-3 measure for informal methods. Moreover, we have also included two variables to capture the structural features of the firm, including whether it is involved in international markets and whether it was a member of a wider group. Both variables have been found in previous research to shape innovative performance (MacGarvie, 2006). Finally, as patterns of innovation may differ across industry and countries, we have included 10 industry dummies and a dummy for whether the firm was French.

4. Results

4.1. Descriptive statistics

(Insert Table 1)

Table 1 shows that French firms are slightly more productive, are larger and are investing more in R&D. Cooperation is more in use in France, and obstacles (financial and non financial) are more frequent too. Finally, French firms are more present in the international market and they more often belong to a group.

However, UK firms are more engaged in training, they have access to more sources of innovation and they tend to protect more their innovations.

(Insert Table 2)

Describing the three forms of innovation (Table 2), process innovation is broadly used by firms in the pool sample as 68% of firms had innovated in process. 64% of firms introduced organizational innovation whereas half of them (51%) introduce product innovation. We have found some differences between France and UK. Especially, French firms are more prone to introduce process innovation than UK firms. Three out of four French firms introduced process whereas half of UK firms in the same period did so. Concerning organizational innovation, 61% of UK firms and 66% of French firms respectively introduce this form of innovation.

Concerning the combinations of innovation forms, among firms with technological activities the most frequent is the use of all the three forms of innovation *i.e.* product, process and organization at the same time, and this suggests that there is some value in the complementarity theory. This situation represents 26% of firms for the pool sample, 21 % for UK and 30% for France. The second most frequent state concerns firms using at the same time process and organizational innovation without introducing product innovation respectively 21%, 16% and 24% for pool, UK and France samples. Introducing no innovations represents in the pool sample 8.5%, 11% of UK firms and 6.5% of French firms. Introducing only one form of innovation is around 5% to 12%. The most frequent innovation form used alone is process innovation. We now undertake to uncover the main determinants of the different forms of innovation, considering first each form of innovation by a trivariate probit, and then refining the analysis by studying each exclusive combination of forms of innovation by a multinomial logit.

4.2.Determinants of the forms of innovation (Trivariate probit)

(Insert Table 3)

A large number of variables in CIS4 appear to be significant determinants of the probability of innovating at least in one of the three forms of innovation (Table 3). Note that a firm may innovate in more than one form, and also that non innovation corresponds to trying or abandoning a technological innovation project – which means that the estimated effects are expected to be generally weaker compared to a case where the reference sample would be composed of firms having no activity in technological innovation.

Size has a positive effect on both process and organizational innovation, but not on product innovation, both in the pooled sample and each of the two countries. A positive influence could be expected for reasons of returns to scale, but product differentiation in large firms may explain the absence of effect of size on product innovation in the firms today.

Internal R&D has completely different effects on the three forms of innovation. In the pooled sample, it affects positively product innovation, negatively process innovation, and has no effect on organizational innovation[2]. If the positive effect on product innovation was expected, the negative effect on process innovation (non significant in UK) may be explained by the fact that process innovation is new to the firm but not to the rest of the world, while product innovation in our study is defined as new to the market. Therefore when internal R&D is focused on product innovation new to the market, it is possible and cheaper to buy or copy some process innovations. Finally we note that R&D has a positive effect on organizational innovation in UK, while it is not significant in France.

Training has an important impact on both process and organizational innovation, and this is in line with the view that the implementation of these innovations requires adapting human skills, while R&D expenditures cover researcher's salaries and play a similar role for product innovation.

Cooperation with other firms or institutions has a positive effect on all forms of innovation, and this result confirms the importance of obtaining external information. The importance of the quest for knowledge and openness of the firm is confirmed by the positive effect of the variable "sources" for all forms of innovation.

The lack of knowledge plays no role except for organizational innovation where the variable has a positive effect. The same odd result is obtained for the financial obstacles. The market obstacles (barriers by incumbents to entry, uncertain demand for innovative goods) have the expected negative sign, but it is not always significant.

The degree of protection of the firm's innovation is an important theoretical determinant of the effort to innovate. CIS is interesting in that respect since it distinguishes formal and informal (or strategic) protection. Informal protection through secrecy, complexity of design or lead time on competitors is always a very significant factor which encourages innovation. Formal protection is definitely important for product innovation, relatively important for organizational innovation (except for UK), while the effect is negative for process innovation, at least in UK. This could be expected, since the copy of processes is difficult to detect by the innovator.

Finally the French firms are more innovative, whatever the form of innovation than the British firms, in spite of controls for size and industries.

Most of these results are in line with established theory and other researchers findings, yet some are puzzling, and this could in part be due to the fact that a firm may make different forms of innovation at the same time, and it may build up a factor strategic for one form, while this factor is not at all interesting for another form, and this may end up in fallacious relations –even though estimation is simultaneous.

Overall the correlation of residuals displays different patterns in the two countries. In UK, complementarities between process and organizational innovation and also between product and organizational innovation are observed, and no relation between product and process innovation. In France complementarity between process and organizational innovation also occurs, while there is no relation between product and organizational innovation, and finally we find substitution between product innovation and process innovation. The complementarities are globally looser in France than in UK. However these relations may be affected by unobserved heterogeneity and we use below methods less subject to this criticism.

4.2. Determinants of the exclusive innovation combinations (multinomial logit)

[2] Polder et al.(2010, table 3b) in a CDM model also find a positive effect for R&D in product innovation but insignificant in process and management innovation.

(Insert Table 4)

This analysis (Table 4) compares the effect of the variables studied above on the probability of innovating in a given exclusive combination of forms of innovation whereas the trivariate probit did not distinguish the firms who do different forms of innovation during the same period. The reference situation is again the sample of firms which try or abandon technological innovation.

An overall analysis shows that the number of significant factors increases in the number of different forms of innovation done simultaneously. This hints that firms need a more systematic use of the diverse possible strategies when the aim is innovation in all forms. Only one variable, market obstacles, is never significant, while it is considered as important in innovation theory. R&D is the most often significant factor, in line with theory.

Size becomes a positive factor in the two countries mainly when the firm wants to do all three forms of innovation, and can be interpreted as a permitting factor for such a costly strategy.

R&D has now a positive effect on any combination of innovations in the two countries except for process only, for which it is negative, making more precise the results of the trivariate probit.

Training always increases innovation except when there is only product innovation (or product combined with organizational innovation in UK). Cooperation enhances the probability of innovation, particularly when multiples forms of innovation take place. The recourse to sources of innovation is important for Product innovation and for multiple innovations. The obstacles to innovation do not influence innovation except the financial obstacles in UK when several forms of innovation are done. These financial obstacles actually increase the probabilities. Finally the intellectual protection, formal or not, increases the probability of innovating, although much less in UK.

The analysis shows fairly different patterns of innovations and different determinants between the two countries. The French firms innovate more in all forms except in organizational innovation alone. Cooperation is less often important than in UK. The obstacles of different sorts do not influence innovation at all in France, whereas intellectual protection is much more influential. These differences hint to the existence of an engineering culture in many French firms, R&D oriented and less sensitive to the influences of the external world. One of the explanations is the stylized fact that French firms are more often managed by engineers trained in elite engineering schools.

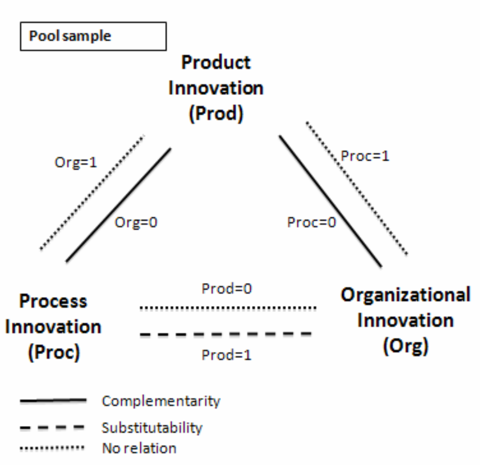
4.3. Testing *complementarities-in-performance* between forms of innovations

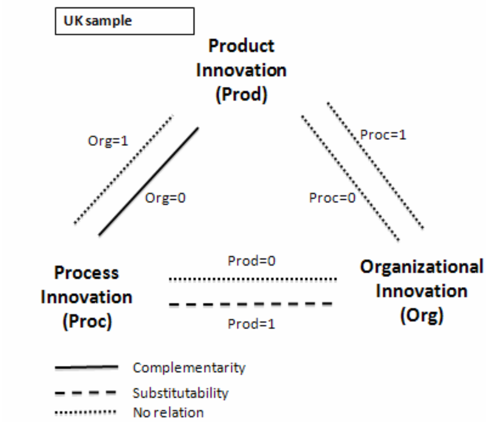
(Insert Table 5)

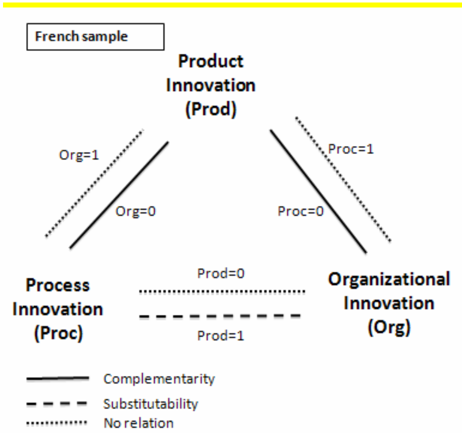
The results of the equation performance first show that all the exclusive combinations of innovation activities have a positive and significant effect on performance. The mere attempt to innovate technologically without any innovation success (W000) has a positive effect, but doing all the forms of innovation at the same time (W111) has the highest effect. While size has no influence, R&D has the expected positive effect on performance. Since innovation activity is controlled for, this direct effect on performance gives credit to the absorption capacity role of R&D. The financial and knowledge obstacles have the right negative sign but are not always significant, while the market obstacles are always significant and have a negative effect. Appropriability methods have no effect on performance, but they have normally been captured in the innovation equations. Finally there is no Country effect.

(Insert Table 6)

Let us now turn to the tests of the complementarities-in-performance. Using a triangle between product, process and organization, the results can be summarized in the following figure:







The triangles present the *conditional* pairwise complementarities and substitutions. A first observation is that we do not find *unconditional* complementarity or *unconditional* substitutability between the three forms of innovation simultaneously, *ie* there is no supermodularity in the three forms of innovations. This is a standard negative result in the econometric studies in this field. It implies to look at pairwise complementarities between innovation forms.

We also observe that we do not obtain *unconditional* complementarities between two forms of innovation. However, we find a number of conditional complementarities and three cases of conditional substitutability.

Looking first at the pooled sample, we observe the three sides of the triangle in turn and find three results. First product and process innovation are found to be conditional complements when (and only when) organizational innovation is not introduced. This result is in line with previous research dealing with complementarity between product and process. It appears as a strategy often technically necessary to make a process innovation to be able to obtain a product new to the market, but it does not require making an organizational change – which has a cost- and this complementarity raises performance. We can name this strategy the "technological strategy". Second, table 6 shows that product and organizational innovations are conditional complements when firms do not use process innovation. Here firms find it efficient to modify their organization to obtain product innovation or make it performant. This is a different practice from the process-product strategy and can be termed a structure oriented strategy in the line of Chandler (1962)[3]. Thirdly a substitution effect exists between process and organizational innovation when firms use product innovation. This suggests that rather than doing the three types of innovation at the same time, a costly strategy, there are two alternative strategies which reach a similar performance, either a process-product innovation complementarity, or an organization-product innovation complementarity. This result has useful implications for managers in order to choose the innovation strategy and the relative magnitude of the coefficients can guide the decision.

[3] See LAM (2010) for a survey of literature on innovative prganizations and typologies of firms

Comparing the triangles in table 6 for France and UK, we found similar results concerning conditional complementarities between product and process innovation when organizational innovation is absent. This result has strong strategic implications for French and UK managers as introducing at the same time product and process innovation does not request to introduce organizational innovation for achieving complementarity effects. However, only for French firms, product and organizational innovations are conditional complements when firms do not use process innovation. This is not the case for UK firms where there is no relation. UK firms should then implement a process-product complementarity strategy while French firms should consider also the organization-product strategy. These somewhat different results for the two countries suggest considering other sample splits. It has long been stated in the management literature under the term of "contingency theory" that the most appropriate structure for a firm is the one that best fits a given operating contingency (Burns & Stalker, 1961). This means that there is no theoretical reason to find a unique best complementarity strategy for all the firms of our sample.

Sample splits

We have conducted additional analysis to determine how the complementarities among product, process and organizational innovations are shaped by the resources and capabilities of the firm. We used firm size and R&D activities as proxies for resource and capabilities respectively. In the case of size, we used the common distinction between small and medium sized firms with less than 250 employees and large firms greater than 250 employees. The triangles (appendix 1) show that the relations between the forms of innovation differ. To make a concise comparison let us count the number of each type of conditional relation for the three samples (pool, UK, France). For large firms, we find 3 complementarities, 15 non relations and no substitubility. For small firms, we find 6 complementarities, 10 non relations and 2 substitutions. The substitutions occur between process and organization innovation when product innovation is present. This is easily explained in terms of the costs of a triple innovation strategy for small and medium firms. The corresponding conditional strategies for the large firms show the opposite relation, namely complementarity for the UK and the pool samples, and no relation for the French sample. The size split then shows that the small and medium firm are responsible for the results of the full sample with two alternative strategies, "technological", and "structure oriented". The large firms have a third strategy which combines organizational change and process innovation. This strategy is likely to be financially allowed by the economies of scale that large firms have.

Let us look now at the role of capabilities in shaping innovation strategies.Capabilities were captured by whether the firm had greater (or lower than) levels of R&D expenditures per staff member than their industry average (using a 10 industry classification (Appendix 2). For the high R&D firms, we find 7 conditional complementarities, 11 non relations, and no substitutability. For the low R&D firms we find 4 complementarities, 10 non relations, and 4 substitutabilities. The differences in strategies are here neater than along the size split. High R&D firms need more than low R&D firms to undertake complementary strategies and their performance benefit from these complementarities. If the pooled sample of high R&D firms shows that the two preferred strategies are those displayed in the full sample, "technological strategy" and "structure oriented strategy", this result is driven by the French firms, and again the UK firms choose the "technological strategy". The low R&D results show less coherence, which can be expected.

5. Conclusions, limitations and further research

These results on sample splits confirm that the nature of complementarities-in-performance between forms of innovation is strongly dependent on the nationality, the resources and specially the capabilities of the firm. They do not invalidate the theory of complementarities-in-performance – showing that they are numerous. One of the main contributions of the paper is that one has to go far beyond the naïve view that there could be one best complementarity strategy, one which would also combine all innovations ("general supermodularity"). Such a policy would obviously have high cost and might also have little effect in many contexts. More precisely we show that the national context is shown to explain strategies, and so are the resources and the capabilities of the firms.

Although this has helped to deepen and extend our understanding of complementarities between different forms of innovation within and across countries, many questions remain. First, our study relies on information from a single wave of the CIS, and with the emergence of panels of CIS data for some countries, it will be possible to investigate these relationships with greater statistical precision and rigor. This approach will help to determine the direction of causality, which can never adequately be addressed in a cross-sectional analysis. This analysis could also provide insights in the timing of the complementarities between different forms of innovation and how the mixing and matching of different forms of innovation shapes subsequent performance. However despite the allure of panels for improving estimations of these relationships, the cost of the use of such panels is the loss of international comparability, which is a critical component of this study.

Second, the concept of organizational innovation covered in this paper is a broad one and measures used in the CIS to capture this concept are generally poor. Following the OECD's Oslo Manual Innovation researchers have often referred to this form innovation as 'non-technological innovation', which is a vague and incomplete description of a rich and varied phenomenon. Indeed, defining something by something it is not can lead to an under appreciation of the specific features of the thing itself. The concept of organizational innovation opens a range of questions about the organization and design of the firm and how choices about what forms of practices and implementation of these practices shape performance outcomes, especially when combined with product and process innovations, which can only be suggested at in a study of this type. It would be fruitful to link surveys focused on organization and organizational change to CIS data[4]. Furthermore, it would be worthwhile to develop more robust measures of organizational innovation on future CIS surveys as well as an extend the survey to explore the factors that explain this form of innovation, away from the current focus of the survey on explaining only technological product and process innovation.

Third, in our study we focus on one type of performance outcome, labour productivity. The selection of labour productivity was based on data availability and the desire to conform to past research. However, there is a wide range of measures of performance that could be investigated, subject to data availability, including firm growth, return on assets, survival, profits and innovative performance. It may be the benefits of combining different forms of innovation drive different performance outcomes.

Finally, we focus on three forms of innovation in this study, but of course, researchers have identified a wider range of innovation forms, including business model innovations or branding innovations. Of course, the greater the number of forms of innovation, the more challenging it will be to make sense of the complementarities that emerge between them. Attempts to measure and discriminate between these different forms of innovation could offer the potential to learn more about the broad combinatorial nature of innovation as originally formulated by Schumpeter and provide lessons for managers and policy-makers as they consider the best ways of promoting economic development.

References

Ahuja, G. 2000. Collaboration networks, structural holes and innovation: a longitudinal study. ***Administrative Science Quarterly***, 45: 425-455.

Argote, L., McEvily, B., & Reagans, R. 2003. Managing Knowledge in Organizations: An Integrative Framework and Review of Emerging Themes. ***Management Science***, 49(4): 571-582.

Arora, A., & Gambardella, A. 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. ***The Journal of Industrial Economics***, 38: 361-379.

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

[4] For example Von Reenan (2007) contains some usefull data on structure and management

Belderbos, R., Carre, M., & Lokshin, B. 2006. Complementarity in R&D Cooperation Strategies. ***Review of Industrial Organization***, 28: 401-426.
Burns, T. & Stalker ,G.M. 1961. The management of innovation. London:Tavistock.
Cassiman, B., & Veugelers, R. 2006. In Search of Complementarity in Innovation
Strategy. ***Management Science***, 52(1): 68-82.
Chandler, A. D.1962. Strategy and Structure: Chapters in the History of the American Idustrial Enterprise.Cambridge MA: MIT Press.
Cohen, W. M. 1995. Empirical Studies of Innovative Activities. In P. Stoneman (Ed.), ***Handbook of the Economics of Innovation and Technological Change***. Oxford: Basil Blackwell.
Cohen, W. M., & Levinthal, D. A. 1990. Absorptive capacity: A new perspective of learning and innovation. ***Administrative Science Quarterly***, 35(1): 128-152.
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: 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, E., & Mairesse, J. 1998. Research Innovation and Productivity: An Econometric Analysis at the Firm Level. ***Economic of INnovation and New Technologies***, 7: 115-158.
Edgerton, D. 1999. From Innovation to Use: ten (eclectic) theses on the history of technology. ***History and Technology***, 16: 1-26.
Ennen, E., & Richter, A. 2010. The Whole Is More Than The Sum of Its Parts - Or Is It? A Review of the Empirical Literature on Complementarities in Organizations. ***Journal of Management***, 36(1): 207-233.
Freeman, C., & Soete, L. L. G. 1997. ***The Economics of Industrial Innovation***. London: Pinter.
Galia, F. & Legros, D. 2004. Complementarities between Obstacles to Innovation: Evidence from France, ***Research Policy***, 33(8).
Gault, F., & Foray, D. 2003. Measuring Knowledge Management in the Business Sector: First Steps. Paris: OECD.
Griffith, R., Heurgo, E., Mairesse, J., & Peters, B. 2006. Innovation and productivity across four European countries. ***Oxford Review of Economic Policy***, 22(4).
Kraft, K. 1990. Are product- and process-innovations independent of each other? ***Applied Economics***, 22: 1029-1038.
Lam, A. 2010. Innovative Organizations: Structure, Learning and Adaptation, in "Innovation Perpective for the 21th century, Madrid: BBVA, 163-175.
Laursen, K., & Foss, N. J. 2003. New HRM Practices, Complementarities and the Impact on Innovative Performance. ***Cambridge Journal of Economics***, 27(2): 243-263.
Laursen, K., & Salter, A. 2004. ***Open for Innovation***. Paper presented at the Academy of Management, New Orleans.
Laursen, K., & Salter, A. 2006. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. ***Strategic Management Journal***, 27(2): 131-150.
Leiponen, A. 2005. Skills and innovation. ***International Journal of Industrial Organization***, 23: 303-323.
Lippman, S., & Rumelt, R. 1982. Uncertain Imitability: An Analysis of Interfirm Differences in Efficiency under Competition. ***The Bell Journal of Economics***, 13(2): 418-438.
Lööf, H., & Heshmati, A. 2003. The Link Between Firm-Level Innovation and Aggregate Productivity Growth: A Cross-Country Examination. ***Research Evaluation***, 12: 131-147.
MacGarvie, M. 2006. Do Firms Learn from International Trade? ***Review of Economics and Statistics***, 88(1): 46-60.
Mairesse, J., & Mohnen, P. 2005. The importance of R&D for innovation: a reassessment using French survey data. ***Journal of Technology Transfer***, 30(1/2): 183-197.
March, J. G. 1991. Exploration and Exploitation in Organization Learning. ***Organization Science***, 2(1): 71-87.
Martinez-Ros, E. 2000. Explaining the decisions to carry out product and process innovations: the Spanish case. ***Journal of High Technology Management Research***, 10(2): 223-242.
Martínez-Ros, E., & Labeaga, J. 2009. Product and process innovation: Persistence and complementarities. ***European Management Review***, 6(1): 64-75.
Milgrom, P. R., & Roberts, B. M. 1990. The Economics of Modern Manufacturing Technology, Strategy and Organization. ***American Economic Review***, 80: 511-528.
Milgrom, P. R., & Roberts, B. M. 1995. Complementarities and Fit: Strategy, Structure and Organizational Change in Manufacturing. ***Journal of Accounting and Economics***, 19: 179-208.

Miravete, E., & Pernias, J. 2006. Innovation complementarity and scale of production. ***Journal of Industrial Economics***, LIV(1): 1-29.
Mohnen, P., & Roller, L. 2005. Complementarities in innovation policy. ***European Economic Review***, 49(6): 1431-1450.
Mol, M., & Birkinshaw, J. 2009. The sources of management innovation: When firms introduce new management practices. ***Journal of Business Research***, 62: 1269-1280.
Mowery, D. C. 1983. The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900-1940. ***Explorations in economic history***(20): 351-374.
Nelson, R., & Winter, S. 1982. ***An Evolutionary Theory of Economic Change***. Cambridge, MA: Harvard University Press.
Ocassio, W. 1997. Towards an attension-based view of the firm. ***Strategic Management Joural***, 19(Summer Special Issue): 187-206.
OECD. 1997. Proposed guidelines for collecting and interpreting technological innovation data: the 'Oslo Manual'. Paris: Organisation for Economic Development and Co-operation.
OECD. 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. Paris: Organisation for Economic Co-operation and Development.
Ordonez, L., Schweitzer, M. E., Galinsky, A., & Bazerman, M. 2009. Goals gone wild: How goals systematically harm individuals and organizations. ***Academy of Management Perspectives***, 23(1).
Percival, J. C., & Cozzarin, B. P. 2008. Complementarities Affecting the Returns to Innovation. ***Industry and Innovation***, 15(4): 371-392.
Polder, M.,van Leeuwen, G., Mohnen, P.& Raymond, W. 2010. product, process and organizational innovation: drivers, complementarity and productivity effects.UNU-MERIT working paper.
Reichstein, T., & Salter, A. 2006. Investigating the sources of process innovation among UK manufacturing firms. ***Industrial and Corporate Change***, 15 (4): 653 - 682.
Rivkin, J. W. 2000. Imitation of Complex Strategies. ***Management Science***, 46(6): 824--844.
Roper, S., Du, J., & Love, J. 2008. Modelling the innovation value chain. ***Research Policy***, 37: 961-977.
Schmidt, T., & Rammer, C. 2007. Non-technological and Technological Innovation. In ZEW (Ed.), ***Discussion Paper***: Centre for European Economic Research
Smith, K. 2005. Measuring Innovation. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), ***The Oxford Handbook of Innovation***: 148-179. Oxford: Oxford University Press.
Teece, D. J. 1986. Profiting from technological innovation: Implications for integration collaboration, licensing and public policy. ***Research Policy***, 15: 285-305.
Tether, B. S. 2002. Who co-operates for innovation, and why: An empirical analysis. ***Research Policy***, 31(6): 947-967.
Tushman, M., & O'Reilly, C. 1997. ***Winning through Innovation: A practical guide to leading organizational change and renewal***. Boston, Mass: Harvard Business School Press.
Utterback, J. M. 1994. ***Mastering the Dynamics of Innovation***. Boston: Harvard Business School Press.
Van Reenen, J., & Bloom, N. 2007. Measuring and explaining management practices across firms and countries. ***Quarterly Journal of Economics***, 122(4): 1351-1408.
Womack, J., & Jones, D. 2005. ***Lean Solutions: How Companies and Customers Can Create Value and Wealth Together***. New York: Free Press.
Womack, J., Jones, D., & Roos, D. 1991. ***The Machine That Changed The World: The Story of Lean Production***. New York: Harper.
Womack, J. P., & Jones, D. T. 1996. ***Lean Thinking***. London: Simon & Schuster.

Table 1: Definition of variables and descriptive statistics

Name of variables	*Description*	*All* (9318 firms)	*UK* (3627 firms)	*France* (5691 firms)
Product innovation	If the firm introduces a product that is new-for-the-market (0,1)	28.40 %	27.40 %	29.03 %
Process innovation	If the firm introduces a new process (0,1)	37.88 %	30.63 %	42.50 %
Organizational innovation	If one of the following: new or significant improved organizational structure, system for managing knowledge, or marketing activities (0,1)	46.39 %	43.64 %	48.15 %
Labour productivity	Sales per employee (in Euro and logs)	4.87	4.70	4.97
Size	Log of number of FTE employees	4.33	4.11	4.46
R&D	Amount of internal R&D expenditures per employee (in Euros and logs)	0.47	0.37	0.54
Training	Dummy for firms investing in training for innovation (0,1)	39.87 %	49.84	33.51
Cooperation	If innovation cooperation arrangements with other firms or institutes (0,1)	33.33 %	20.10	48.33
Openness	Number of 'important' or 'very important' sources of innovation: internal, suppliers, customers, consultants competitors, universities, public research institutes, conferences, scientific and trade publications, and professional and industry associations (0-10)	2.73	3.68	2.13
Financial obstacles	If lack of finance inside or outside the firm is 'very important' or 'important' (0,1)	44.61%	31.07	53.24
Knowledge obstacles	If lack of qualified personnel, lack of information on technology or lack of information on market are 'very important' or 'important' (0,1)	46.94%	43.75	48.97
Market obstacles	If market dominated by established enterprises or uncertain demand for innovative good or services are 'very important' or 'important' (0,1)	51.94%	49.79	53.31
Formal appro-priability	Number of formal methods for protection for innovation, including registration of designs, trademarks, patents and copyrights (0-4)	1.15	1.53	0.91
Informal appro-priability	Number of informal methods of protection for innovation, including secrecy, complexity of design or lead-time advantage on competitors	1.10	1.72	0.71
International market	Dummy for firms operating in 'European' or 'International' markets (0,1)	66.84%	61.79	70.07
Group	Dummy for firms belonging to a group (0,1)	52.74%	41.36	59.99
Industry	Dummies for: Textile, Paper, Chemical, Plastics and rubber, Basic metals, Fabricated metal, Machinery, Electric equipments, Transport equipment and other for the remaining firms.			
French	Dummy for French firms (0,1)	61.08%		

Sources: CIS 4 (UK and France)

Table 2: Descriptive statistics of forms of innovations and the eight exclusive associated combinations

	All	*UK*	*France*
Product innovation	2646 (50.74%)	994 (49.35%)	1652 (51.61%)
Process innovation	3530 (67.69%)	1111 (55.16%)	2419 (75.57%)
Organizational innovation	3336 (63.97%)	1217 (60.43%)	2119 (66.20%)
None (W000)	445 (8.53%)	239 (11.37%)	206 (6.44%)
Product innovation only (W100)	374 (7.17%)	192 (9.53%)	182 (5.69%)
Process innovation only (W010)	637 (12.21%)	229 (11.37%)	408 (12.75%)
Organizational innovation only (W001)	395 (7.57%)	229 (11.37%)	166 (5.19%)
Product and process innovation (W110)	423 (8.11%)	137 (6.80%)	286 (8.93%)
Product and organizational innovation (W101)	471 (9.03%)	243 (12.07%)	228 (7.12%)
Process and organizational innovation (W011)	1092 (20.94%)	323 (16.04%)	769 (24.02%)
All forms of innovations (W111)	1378 (26.42%)	422 (20.95%)	956 (29.87%)
Nb of firms with technological innovating activities (Product, Process and or Project)	5215	2014	3201

Sources: CIS 4 (UK and France)

Table 3: Forms of innovations: Trivariate Probit

	Pooled		***UK***		***France***	
	Coef.	z	Coef.	z	Coef.	z
Product Innovation						
Size	0,023	1,53	-0,037	-1,55	0,051**	2,60
R&D (log)	0,268***	12,98	0,286***	6,98	0,242***	10,20
Training	0,002	0,04	-0,016	-0,25	0,007	0,13
Cooperation	0,263***	6,59	0,378***	5,78	0,181***	3,55
Openness	0,021**	2,21	0,026*	1,78	0,020*	1,64
Financial obstacles	0,043	1,11	0,065	1,03	0,031	0,62
Knowledge obstacles	0,027	0,71	0,083	1,34	0,004	0,08
Market obstacles	-0,014	-0,37	-0,122*	-1,94	0,058	1,14
Formal appropriability	0,109***	7,45	0,097***	4,58	0,156**	7,09
Informal appropriability	0,170***	9,49	0,098***	3,04	0,220***	9,95
France	0,212***	4,35				
Constant	-0,964***	-9,73	-0,579***	-3,99	-0,936***	-6,84
Process Innovation						
Size	0,064***	4,15	0,082***	3,47	0,052**	2,51
R&D (log)	-0,085***	-3,96	-0,031	-0,79	-0,115***	-4,39
Training	0,461***	11,56	0,462***	7,39	0,465***	8,90
Cooperation	0,226***	5,43	0,318***	4,89	0,156***	2,85
Openness	0,018*	1,87	0,018	1,27	0,022*	1,68
Financial obstacles	0,011	0,28	0,001	0,01	0,011	0,21
Knowledge obstacles	0,064*	1,63	0,077	1,26	0,049	0,93
Market obstacles	-0,079**	-1,97	-0,063	-1,02	-0,086*	-1,61
Formal appropriability	-0,051***	-3,40	-0,049***	-2,29	-0,036	-1,55
Informal appropriability	0,064***	3,40	0,004	0,14	0,110***	4,56
France	0,644***	13,04				
Constant	-0,603***	-5,98	-0,705***	-4,93	0,209	1,42
Organizational Innovation						
Size	0,093***	6,05	0,119***	4,85	0,071***	3,55
R&D (log)	0,035	1,61	0,139***	3,36	-0,016	-0,61
Training	0,335***	8,69	0,255***	4,04	0,389***	7,86
Cooperation	0,178***	4,40	0,221***	3,31	0,133**	2,58
Openness	0,055***	5,81	0,039***	2,67	0,068***	5,40
Financial obstacles	0,079**	2,00	0,151**	2,36	0,054	1,06
Knowledge obstacles	0,156***	4,02	0,125**	2,01	0,175***	3,46
Market obstacles	-0,001	-0,01	-0,046	-0,74	0,017	0,34
Formal appropriability	0,059***	3,98	-0,011	-0,53	0,135***	5,92
Informal appropriability	0,057***	3,14	0,135***	4,27	0,040*	1,74
France	0,230***	4,74				
Constant	-1,010	-10,00	-1,154***	-7,80	-0,728***	-5,15
Correlations of residuals						
Product / Process	-0,020	-0,87	0,019	0,54	-0,062**	-2,06
Product / Organization	0,050**	2,17	0,079**	2,12	0,034	1,13
Process / Organization	0,226***	9,43	0,185***	4,96	0,265***	8,18

Sources: CIS 4 (UK and France), Industry dummies are not reported

Significance levels at *** 1%, ** 5% and * 10%.

Table 4: Exclusive innovation combinations: Multinomial Logit

	Pooled		*UK*		*France*	
	Coef.	z	Coef.	z	Coef.	z
Product innovation only (W100)						
Size	-0,170***	-2,76	-0,278***	-3,13	-0,079	-0,89
R&D (log)	0,285***	3,28	0,444***	2,89	0,181*	1,69
Training	-0,222	-1,48	-0,179	-0,87	-0,295	-1,31
Cooperation	0,385**	2,32	0,648**	2,55	0,212	0,93
Openness	0,039	1,04	0,081	1,59	-0,023	-0,40
Financial obstacles	0,113	0,73	0,280	1,25	-0,064	-0,29
Knowledge obstacles	-0,126	-0,84	-0,018	-0,08	-0,226	-1,04
Market obstacles	0,026	0,17	-0,185	-0,87	0,273	1,24
Formal appropriability	0,168***	2,99	0,136*	1,86	0,285***	2,81
Informal appropriability	0,206***	2,90	0,151	1,47	0,318***	2,97
France	0,389**	2,10				
Constant	-0,199	-0,54	0,237	0,50	-0,441	-0,67
Process innovation only (W010)						
Size	-0,034	-0,62	-0,056	-0,69	0,004	0,05
R&D (log)	-0,370***	-3,84	-0,309***	-1,54	-0,445**	-4,02
Training	0,721***	5,51	0,825***	4,15	0,692***	3,78
Cooperation	0,170	1,12	0,481*	1,89	-0,059	-0,30
Openness	-0,017	-0,48	0,031	0,64	-0,062	-1,25
Financial obstacles	0,005	0,04	-0,021	-0,10	-0,025	-0,14
Knowledge obstacles	-0,049	-0,37	-0,016	-0,08	-0,089	-0,48
Market obstacles	0,018	0,13	0,153	0,75	-0,028	-0,15
Formal appropriability	-0,171***	-3,11	-0,115	-1,56	-0,158*	-1,68
Informal appropriability	0,093	1,49	-0,019	-0,20	0,199**	2,08
France	0,982***	6,17				
Constant	0,055	0,16	-0,051	-0,11	1,148**	2,15
Organizational innovation only (W001)						
Size	0,018	0,30	0,018	0,23	0,024	0,26
R&D (log)	0,018	0,20	0,325**	2,14	-0,173	-1,41
Training	0,449***	3,07	0,502**	2,53	0,427*	1,93
Cooperation	0,413**	2,54	0,627**	2,59	0,309	1,34
Openness	0,101***	2,78	0,089*	1,84	0,107*	1,90
Financial obstacles	0,159	1,05	0,240	1,13	0,102	0,45
Knowledge obstacles	0,121	0,82	0,045	0,22	0,194	0,87
Market obstacles	0,144	0,96	0,191	0,93	0,049	0,22
Formal appropriability	0,141**	2,52	0,027	0,39	0,301***	2,90
Informal appropriability	0,040	0,57	0,189*	1,92	-0,088	-0,74
France	-0,006	-0,03				
Constant	-1,251***	-3,36	-1,496***	-3,17	-1,311**	-2,00

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	Pooled		UK		France	
	Coef.	z	Coef.	z	Coef.	z
Product and Process (W110)						
Size (logemp4)	-0,006	-0,10	-0,088	-0,94	0,045	0,57
R&D (log)	0,212**	2,48	0,385**	2,32	0,085	0,85
Training	0,607***	4,16	0,690***	2,91	0,613***	3,11
Cooperation	0,708***	4,46	1,141***	4,34	0,412**	2,01
Openness	0,063*	1,69	0,074	1,33	0,045	0,89
Financial obstacles	0,095	0,63	0,080	0,33	0,066	0,33
Knowledge obstacles	0,120	0,82	0,222	0,95	0,034	0,17
Market obstacles	-0,037	-0,25	0,062	0,26	-0,045	-0,23
Formal appropriability	0,100*	1,77	0,120	1,47	0,206**	2,21
Informal appropriability	0,358***	5,21	0,163	1,36	0,493***	5,10
France	1,361***	7,34				
Constant	-2,181***	-5,71	-2,098***	-3,69	-0,641	-1,15
Product and Organization (W101)						
Size (logemp4)	0,051	0,91	-0,011	-0,13	0,103	1,24
R&D (log)	0,368***	4,48	0,569***	3,94	0,233**	2,29
Training	0,443***	3,10	0,288	1,45	0,609***	2,91
Cooperation	0,249	1,57	0,628**	2,62	-0,124	-0,56
Openness	0,094***	2,65	0,108**	2,25	0,080	1,51
Financial obstacles	0,234	1,59	0,372*	1,76	0,169	0,80
Knowledge obstacles	0,212	1,48	0,285	1,42	0,123	0,59
Market obstacles	0,108	0,74	-0,020	-0,10	0,231	1,09
Formal appropriability	0,194***	3,60	0,098	1,41	0,428***	4,46
Informal appropriability	0,316***	4,55	0,321***	3,01	0,402***	3,98
France	0,543***	3,03				
Constant	-2,103***	-5,73	-1,899***	-3,96	-1,793***	-3,00
Process and Organization (W011)						
Size	0,084*	1,69	0,168**	2,25	0,061	0,87
R&D (log)	-0,262***	-3,25	-0,033	-0,21	-0,411***	-4,34
Training	0,990***	8,12	0,820***	4,39	1,089***	6,40
Cooperation	0,414***	3,02	0,597***	2,60	0,212	1,19
Openness	0,105***	3,39	0,109**	2,42	0,090**	2,04
Financial obstacles	0,160	1,27	0,337*	1,69	0,049	0,29
Knowledge obstacles	0,265**	2,15	0,233	1,24	0,255	1,50
Market obstacles	-0,058	-0,47	-0,091	-0,48	-0,017	-0,10
Formal appropriability	-0,019	-0,39	-0,126*	-1,91	0,150*	1,80
Informal appropriability	0,143**	2,47	0,225**	2,55	0,196**	2,23
France	1,335***	8,87				
Constant	-1,367***	-4,29	-1,928***	-4,28	0,238	0,48
Product, Process and Organization (W111)						
Size	0,176***	3,55	0,135*	1,84	0,201***	2,88
R&D (log)	0,267***	3,58	0,607***	4,37	0,077	0,86
Training	1,151***	9,17	1,130***	5,79	1,206***	6,92
Cooperation	0,993***	7,29	1,486***	6,76	0,623***	3,46
Openness	0,132***	4,29	0,136***	3,05	0,125***	2,81
Financial obstacles	0,215*	1,69	0,326*	1,65	0,129	0,74
Knowledge obstacles	0,279**	2,25	0,321*	1,72	0,237	1,37
Market obstacles	-0,082	-0,65	-0,286	-1,51	0,051	0,30
Formal appropriability	0,179***	3,76	0,077	1,18	0,388***	4,70
Informal appropriability	0,446***	7,59	0,338***	3,43	0,560***	6,44
France	1,568***	10,10				
Constant	-3,382***	-10,26	-3,179***	-6,80	-1,781***	-3,51

Sources: CIS 4 (UK and France), Industry dummies are not reported Significance levels at *** 1%, ** 5% and * 10%.

Table 5: Exclusive innovation combinations and performance

	Pooled		UK		France	
	Coef.	z	Coef.	z	Coef.	z
W000	0,808***	18.05	0,843***	7.71	0,758***	5.35
W100	0,779***	17.13	0,813***	7.45	0,723***	5.16
W010	0,826***	18.47	0,876***	7.97	0,759***	5.23
W001	0,812***	17.73	0,866***	7.80	0,734***	5.16
W110	0,845***	18.27	0,903***	8.00	0,773***	5.33
W101	0,845***	18.33	0,878***	8.00	0,789***	5.47
W011	0,827***	18.48	0,880***	8.07	0,758***	5.31
W111	0,843***	18.57	0,886***	7.93	0,775***	5.43
Prod (2002)	0,862***	135.42	0,833***	32.57	0,886***	53.89
Size	-0,001	-0.19	0,009	1.25	-0,006	-0.78
R&D (log)	0,022***	4.63	0,045***	3.79	0,011*	1.81
Training	0,011	1.16	0,020	1.25	0,005	0.52
Cooperation	-0,001*	-0.12	-0,012	-0.74	0,004	0.42
Openness	-0,001	-0.68	-0,002	-0.49	-0,002	-0.56
Financial obstacles	-0,049***	-5.27	-0,013	-0.78	-0,076***	-4.06
Knowledge obstacles	-0,022***	-2.28	-0,010	-0.54	-0,027	-2.26
Market obstacles	-0,025***	-2.74	-0,043***	-2.70	-0,010**	-0.97
Formal appropriability	-0,005	-1.17	0,003	0.52	-0,016	-1.52
Informal appropriability	0,001	0.26	-0,001	-0.19	0,003	0.59
France	-0,017	-1.47				

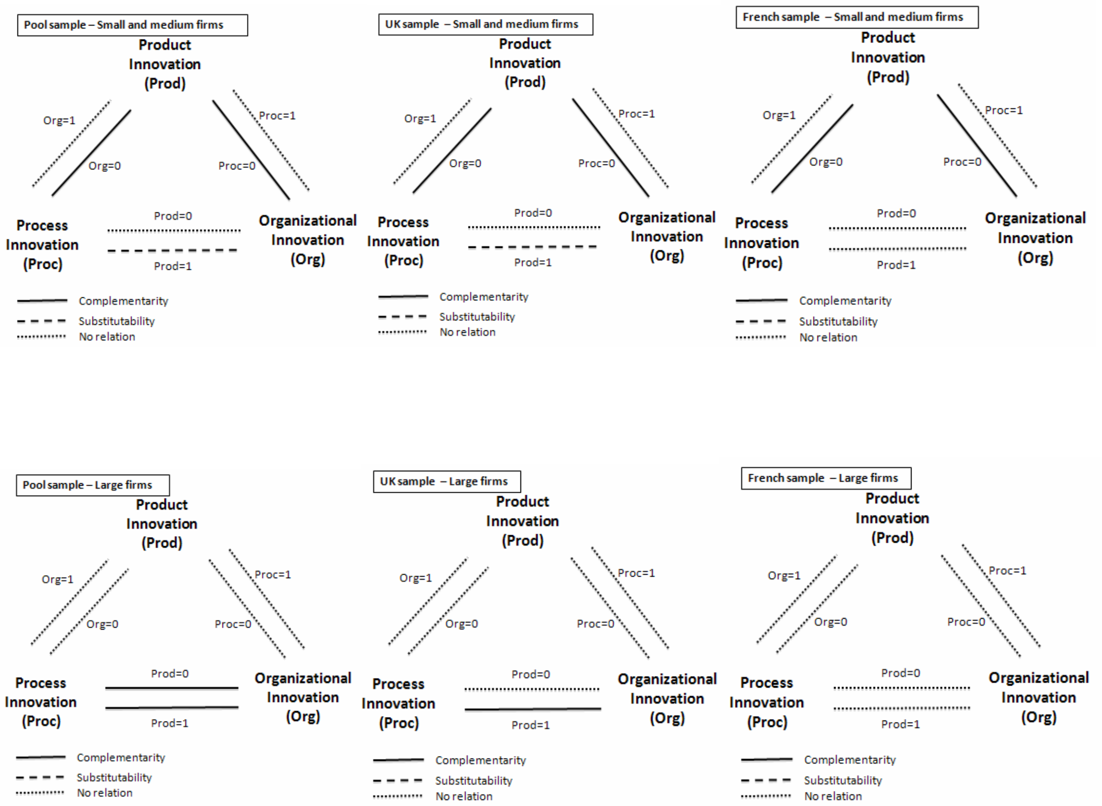
Sources: CIS 4 (UK and France), Industry dummies are not reported
Significance levels at *** 1%, ** 5% and * 10%.
Wijk refers to the exclusive innovation combinations: the combination of innovations forms (0/1, 0/1, 0/1) reflect whether a firm has introduced a product, process and/or organizational innovation.
All the tests reject the independence between the selection and the performance equation.
Dropping R&D from this equation performance did not change the results.

Table 6: Testing *complementarities-in-performance* between forms of innovations

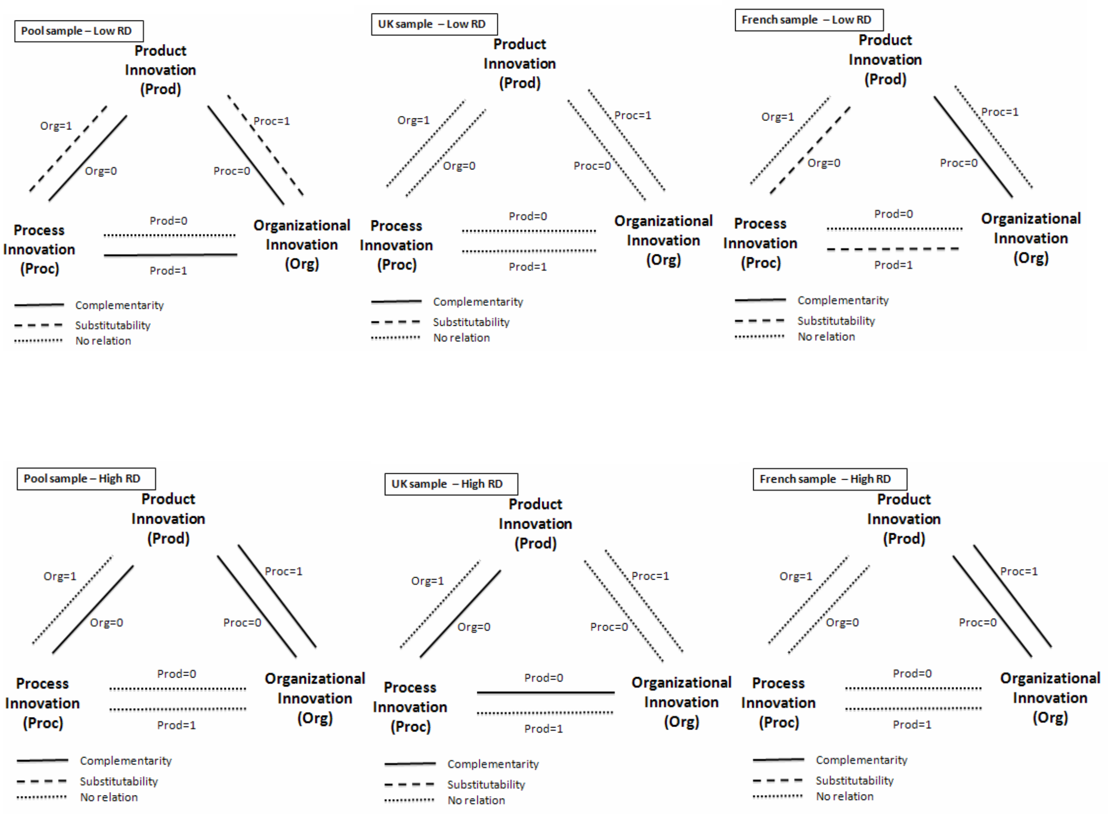
		Pool		UK		FR	
		Chi2	Prob Chi2	Chi2	Prob Chi2	Chi2	Prob Chi2
Product / Process	**H0: *(a)* C1=0 & *(b)* C2=0**	3.39	0.184	1.83	0.399	3.21	0.201
	Organizational innovation = 0:						
	H0: *(a)* C1=W110+W000-W010-W100 >/< 0 ?	2.84*	0.092	1.81	0.178	1.89	0.169
	Complements (C1>0) / Substitutes (C1<0)	**COMPL.**	**0.954**	**COMPL.**	**0.911**	**COMPL.**	**0.915**
	Organizational innovation = 1:						
	H0: *(b)* C2=W111+W001-W011-W101 >/< 0 ?	0.53	0.467	0.01	0.905	1.33	0.248
	Complements (C2>0) / Substitutes (C2<0)	NONE	0.233	NONE	0.452	NONE	0.124
Product / Organization	**H0: *(a)* C1=0 & *(b)* C2=0**	4.49*	0.010	1.29	0.525	4.55**	0.010
	Process innovation = 0:						
	H0: *(a)* C1=W101+W000-W100-W001 >/< 0 ?	4.47**	0.035	1.07	0.302	4.53*	0.033
	Complements (C1>0) / Substitutes (C1<0)	**COMPL.**	**0.983**	NONE	0.849	**COMPL.**	**0.983**
	Process innovation = 1:						
	H0: *(b)* C2=W111+W010-W110-W011 >/< 0 ?	0.02	0.896	2.24	0.624	0.02	0.875
	Complements (C2>0) / Substitutes (C2<0)	NONE	0.448	NONE	0.312	NONE	0.562
Process / Organization	**H0: *(a)* C1=0 & *(b)* C2=0**	6.42**	0.040	3.56	0.169	3.54	0.170
	Product innovation = 0:						
	H0: *(a)* C1=W011+W000-W010-W001 >/< 0 ?	0.01	0.920	0.29	0.592	0.50	0.478
	Complements (C1>0) / Substitutes (C1<0)	NONE	0.460	NONE	0.296	NONE	0.761
	Product innovation = 1:						
	H0: *(b)* C2=W111+W100-W110-W101 >/< 0 ?	6.41**	0.011	2.24*	0.072	3.03	0.082
	Complements (C2>0) / Substitutes (C2<0)	**SUBST.**	**0.994**	**SUBST.**	**0.964**	**SUBST.**	**0.959**
	Nb of observations	9318		3627		5691	
	Nb of uncensored obs.	5215		2014		3201	

Sources: CIS 4 (UK and France)
Significance levels at *** 1%, ** 5% and * 10%
Wijk refers to the exclusive innovation combinations: the combination of innovations forms (0/1, 0/1, 0/1) reflect whether a firm has introduced a product, process and/or organizational innovation.
All the tests reject the independence between the selection and the performance equation.

Appendix 1: Testing *complementarities-in-performance* between forms of innovations for small and medium firms (less than 250 empl.) and large firms (more than 250 empl.)



Appendix 2: Testing *complementarities-in-performance* between forms of innovations for low and high RD firms



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