Firm persistence in technological innovation: the relevance of organizational innovation

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Firm persistence in technological innovation:
The relevance of organizational innovation (*)

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Abstract

Organizational innovation favors technological innovation, but does it also influence persistence in technological innovation? This article empirically investigates the pattern of technological innovation persistence and tests the potential impact of organizational innovation using firm-level data from three waves of French Community Innovation Surveys. The evidence indicates a positive effect of organizational innovation on persistence in technological innovation, according to various measures of organizational innovation. Moreover, this impact is more significant for complex innovators, i.e. those who innovate in both products and processes. The results highlight the complexity of managing organizational practices with regard to the technological innovation of firms. They also add to understanding of the drivers of innovation persistence through the focus on an often-forgotten dimension of innovation in a broader sense.

Keywords: Organizational Innovation, Technological Innovation, Persistence

JEL CLASSIFICATION: O31, C23, C25, L20

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Introduction

Economic analyses of innovation persistence mainly focus on technological changes or drivers of technological innovation persistence. Yet firms' innovation capabilities do not depend solely on their internal technological competencies (e.g. R&D activities). Rather, their ability to develop a broad set of complementary activities and organizational strategies appears crucial for increasing the performance of their innovation processes. The importance of managing different types of resources, including non-technological ones, has been highlighted already in the resource-based view of the firm and evolutionary economic theory (e.g., Nelson and Winter 1982; Wernerfelt 1984; Teece 1988). Firms that combine customer, technological, and organizational skills bring more innovations to the market (Lokshin, Van Gils, and Bauer 2008).

Yet research is only beginning to shed light on the 'very complex and under-investigated topic' (Evangelista and Vezzani 2010, 1262) of the relationships between technological and non-technological innovations. The importance of both types of innovation and the related need for their coexistence and co-evolution for firm performance, is clear (Damanpour and Aravind 2012). Broadening the scope of analysis beyond the technological domain is crucial for understanding firms' economic performance because complex types of organizational innovation forms help explain such performance. In line with recent studies that demonstrate the influence of organizational innovation strategies on technological innovation outcomes, we highlight the effect of non-technological (or 'organizational') innovation on firms' technological innovation persistence. Similar to Peters (2009), we also assert that innovation persistence exists any time a firm that has innovated in one period innovates again in a subsequent period.

Prior research has tended to concentrate on the probability of introducing new organizational practices during a reference period, a focus that fails to account for the degree of diversity of organizational innovations or the temporal continuity of organizational change. Thus, these approaches cannot assess some key aspects of organizational innovation, such as diversity, continuity, or the impact on dynamic firm innovation behaviors. To fill this gap, we consider the specific role of organizational innovation. Despite its clear importance for corporate performance, its potential impact on technological innovation persistence has not attracted sufficient research attention. We highlight the dynamics of innovation in this study and consider the impact of organizational innovation undertaken in period t on technological innovation observed in subsequent periods. Our intention is not to explain the persistency of technological innovation but rather to explore the role of organizational innovation in its dynamics.

Accordingly, we survey existing literature to determine the likely connection between organizational and technological innovations. We then describe our data set and outline our methodology and empirical models. Next, we present and discuss our results and conclude by outlining some limitations of this study and avenues for further research.

Organizational innovation and technological innovation process

This research is based on an underlying assumption: Organizational innovation can have a positive impact on technological innovation processes. We also go a step further to test whether organizational innovation influences the persistence of technological innovation too. To illustrate this relationship, we use the example of an organizational innovation undertaken by the SEB Group (a world leader in small electronic appliances). This innovation prompted a reorganization of all the Group's R&D activities, which in turn increased innovation (especially radical forms). One of the authors of this study also investigated these changes in a decade-long longitudinal analysis (2002–2012). After the firm's R&D activities were totally reconfigured between 2003 and 2010, it integrated an exploratory phase into its innovation process. This new organization isolated the research activities from development; at the end of 2012, it had increased innovation and produced more radically new products, such that new products made up a greater proportion of its total sales (Mothe and Brion 2012).

The neglected role of organizational innovation in technological innovation

Innovation refers to the adoption of an idea, behavior, system, policy, program, device, process, product, or service that is new to the organization (Damanpour 1991). The expanded definition of innovation in the Oslo Manual (OECD 2005) treats organizational innovation as distinct from technological innovation. However, the question remains: How does organizational innovation affect dynamic technological innovation processes?

Lam (2005) proposes two meanings for *organizational innovation*: the creation or adoption of an idea that is new to the organization (organizational innovation *lato sensu*) and changes in managerial practices or types of organizational forms (organizational innovation *stricto sensu*). Theoretically, organizational innovation is a broad concept that encompasses strategic, structural, and behavioral dimensions; however, there is no consensus about its definition. Some studies include all types of innovation under its umbrella (e.g., Daft 1978; Crossan and Apaydin 2010), whereas others, including this study, contrast it with technological innovation (Gumusluoğlu and Ilsev 2009), drawing on the distinction between technological and non-technological innovation (Battisti and Stoneman 2010). Organizational innovations usually account for changes in business practices (and knowledge management) in the organization of the workplace or in the firm’s external relations. In the absence of a unified theoretical definition, we follow the OECD (2005, 52), which views an organizational innovation as ‘the implementation of a new organizational method in the firm’s business practices, knowledge management, workplace organization or external relations’.

Studies of the relationships between organizational and technological innovations often highlight that technological innovation drives organizational changes within the firm (Dougherty 1992), because firms introducing technological innovation must reorganize their production, workforce, sales, and distribution systems. Another research stream suggests an inverse relationship, such that organizational innovation enhances flexibility and creativity, which facilitates the development of technological innovations (Lokshin, Belderbos, and Carree 2008). Teece (1998) explains the links among firm strategy, structure, and the nature of innovation by proposing a set of organizational requirements for the innovation process. He argues that both formal and informal structures, together with the firms’ external networks, powerfully influence the rate and direction of innovative activities. Lam (2005) also proposes that organizational innovation is a necessary precondition of technological innovation. Ganter and Hecker (2013) add that organizational innovations appear to increase a firm's capability to flexibly adapt to dynamic market environments, and/or to drive change by enhancing its ability to technologically innovate.

Another argument in technological innovation literature questions whether firms that pioneer novel forms of organization take full advantage of radical changes in technology. Dougherty’s (1992) model of the renewing organization, which relies on product innovation, conceives the creation and exploitation of knowledge that links market and technological possibilities, in which context innovation, strategy, and organizational design are inextricably linked. Such contributions advance our understanding of the effects of organizational structure on the ability of organizations to learn, create knowledge, and generate technological innovation (Lam 2005), as well as the positive relationship between organizational and technological innovations (Günday et al. 2011). Bharadwaj and Menon (2000) further demonstrate that innovation is a function of individual efforts and organizational systems aimed at facilitating creativity, such that successful product innovation partly depends on organizational factors. According to Mothe and Nguyen-Thi (2012), the effects of non-technological innovations on technological innovation differ with the phase of the innovation process: Organizational innovations can increase the likelihood of a technological innovation but not its commercial success. Using a sample of fast-moving consumer goods firms in Germany, Lokshin, Van Gils, and Bauer (2008) find that firms that implement a combination of customer, organizational, and technological skills tend to introduce more innovations. Tatikonda and Montoya-Weiss (2001) show that organizational process factors appear associated with the performance of new products. Finally, Armbruster et al. (2008) argue that organizational innovations are prerequisites and facilitators of the efficient use of technical product and process innovations.

In addition, some studies have also detailed the impact of different types of organizational innovations on technological innovation. Theories of organizational renewal and organizational design generally have analyzed the impact of design on innovation; in the past decade, a growing body of research (Gibson and Birkinshaw 2004; Tushman et al. 2010) also has attended to the link of organizational design (especially ambidextrous structures) with innovation outputs. Organizational (re)structuring, if it leads to structural renewal (as in our example of the R&D reorganization by the SEB Group), may facilitate other types of innovations (Günday et al. 2011). Jansen, Van den Bosch, and Volderba (2006), analyzing the impact of various organizational arrangements on innovation, show that organizational antecedents differentially affect exploratory and exploitative innovations: Centralization negatively affects exploratory innovation, whereas formalization positively influences exploitative innovation.

Moreover, connectedness within units is an important antecedent of both exploratory and exploitative innovations. We thus infer that adopting organizational innovations geared toward the adoption of new organizational methods (e.g., centralization, formalization, connectedness) influences the type of technological innovation. Another example of the impact of organizational transformation on innovation comes from Verona and Ravasi (2003), who study Oticon, a Danish electronics producer and one of the global market leaders in hearing aids. It gained fame for its radical organizational transformation in the early 1990s, which also provides an outstanding example of the innovative benefits that a radical project-based organization can generate (Verona and Ravasi 2003). Its ‘spaghetti organization’ manifests a flat, loosely coupled, project-based organization characterized by ambiguous job boundaries and extensive delegation of task and project responsibilities to autonomous teams.

Inter-organizational collaboration is another organizational innovation practice that has been recognized as important for supplementing internal innovative activities (Hagedoorn 2002). External relations and networks appear increasingly necessary to support innovative activities (Teece 1992). Un, Cuervo-Cazurra, and Asakawa (2010) theoretically explain and empirically show that various types of collaborations have differential influences on product innovation.

Moreover, knowledge management practices are the heart of value creation and technological innovation, in the knowledge-based view (Grant 1996) and in practice. Effective innovation depends on firms' access and ability to absorb external knowledge (Love and Roper 2009); Wu, Ma and Xu (2009) provide an interesting example of the impact of such organizational learning and knowledge management practices on technological innovation. In an in-depth, longitudinal case study of HY, an air separation plant manufacturer in China, they explain how it managed to accelerate its technological innovation through successful organizational learning over the preceding 20 years.

As these studies consistently acknowledge, organizational practices have crucial influences on competitive advantages and firm innovation, in the sense that they provide input for firm innovation processes and innovation capabilities. Although these works regard organizational innovation as a potential determinant of technological innovation, only one study, to the best of our knowledge, has addressed it in the context of technological innovation persistence. Le Bas and Poussing (2012), using two waves of Community Innovation Surveys (CIS) in Luxembourg, find that implementing organizational innovation has a positive impact on innovation persistence, but only in terms of increasing the probability of becoming a complex innovator. We attempt to go further and deepen analyses of this relationship by considering different organizational innovation measures from a dynamic perspective. Our underlying hypothesis holds that organizational innovation has a positive impact on technological innovation and that the method (i.e., diversity and temporal continuity) chosen by the firm to undertake its organizational changes matters.

Organizational innovation and technological innovation persistence

A growing literature stream has been devoted to technological innovation persistence, with inconsistent results. Works using patent data tend to support non - persistence whereas studies based on innovation surveys show the contrary (for a review of the empirical literature on technological innovation persistence, see Antonelli, Crespi and Scellato 2013). A very recent research has also examined the persistence of organizational innovation (Sapprasert and Clausen 2012). In line with the above-mentioned research, we consider the role of organizational innovation in technological innovation persistence according to three complementary explanations of technological innovation persistence at the firm level (Peters 2009).

First, innovations involve dynamic increasing returns (Nelson and Winter 1982). This so-called knowledge accumulation hypothesis stipulates that experience in innovation is associated with dynamic increasing returns, in the form of learning-by-doing and learning-to-learn effects, which enhance knowledge stocks and the probability of future innovations (Geroski, van Reenen and Walters 1997; Duguet and Monjon 2002; Latham and Le Bas 2006). Learning in this sense pertains to a capacity to innovate later. We might anticipate that new practices for organizing work would drive the changing processes and that new methods of organizing external relations would increase the level of exchanged technological knowledge (learning by interacting) and spur the emergence of improved technologies. Schmidt and Rammer (2007) provide some support for this approach. Taking into account the interrelations across different innovation strategies, they note that the combination of technological and non-technological innovation has a positive impact on effective innovation performance.

Second, the 'success breeds success' approach indicates that firms gain locked-in advantages over other firms through successful innovations. Specifically, innovation feeds profitability, which funds subsequent innovation activities. Economic and commercial successes matter in this regard, and Polder et al. (2010) argue that organizational innovation also plays a role. Product and process innovations, in combination with organizational innovation, positively impact firm productivity. Evangelista and Vezzani (2010) support this view by showing that firms that introduce both technological and organizational innovations have a clear competitive advantage over both non-innovating firms and those introducing technological innovations only. All these studies imply that organizational innovations, used together with technological innovations, exert a positive effect on firm economic performance.

Third, noting sunk costs in R&D activities, Antonelli, Crespi and Scellato (2012), based on the heterogeneity of previous studies' results, especially between those using patent data (which find low innovation persistence) and those relying on CIS data (which discover stronger evidence of persistence), undertake an analysis in which the complementarities between different innovation strategies based on product and process innovation are considered. They find a relatively higher persistence level for product innovation than for process innovation, and more robust evidence of persistence for product innovation than for process innovation when complementarity effects between the two types of innovation are accounted for. The results indicate a true state dependence[1] (i.e., past innovation behavior is an important determinant of current innovation behavior and the state of the period depends on the state of the previous period) for the cases of R&D activities and product innovation in which the routinized behaviour characterizing firms' competitive strategies plays a relevant role in explaining innovation persistence. Antonelli, Crespi and Scellato (2012) interpret evidence of persistence in innovation efforts as inter-temporal stability in R&D efforts. The firm chooses between investing - or not - in R&D activities, and sunk costs encourage the continuity of R&D expenditures. That is, a firm deciding to engage in R&D activities for the first time incurs start-up costs that are not recoverable, and the resulting sunk costs represent a barrier to both entry into and exit from R&D activities (Antonelli, Crespi and Scellato 2012).

At first glance, organizational innovation seems to be irrelevant in this context of R&D activities. This is due to the "*failure to study the impact of research departments and their organization on rates of innovation*" (Hage 1999, 607). In addition, "*paradoxically, very few studies of industrial research departments and their characteristics exist in the literature*" (ibid., 608). The relationship is indeed complex, and the impact on sunk costs depends on the success of organizational innovation. In the case of the implementation or adoption of new methods to interact with external relations and partners, sunk costs are linked to asset specificity: for of specific or co-specialized assets, because they will be difficult to redeploy, sunk costs will increase (if the cooperation fails). If cooperation is successful, then, as for internal organizational innovation, new sources of valorization will be found for the specific assets, thus creating less irreversibility and leading to diminishing sunk costs. In addition, organizational innovations related to the organization of R&D activities may lead to increasing returns on R&D; the (total and sunk) R&D costs should thus decrease over time, which would increase incentives to persist in R&D activities.

[1] The concepts of state dependency and persistence are important in the analysis of outcomes over time. "Persistence" describes whether a particular condition, innovation in our case, is brief or long-lasting, while 'state dependency' indicates whether the chance of experiencing a condition depends on having experienced the same condition in the past.

However, the impact of organizational innovation on total and sunk costs of R&D is not encompassed in our research objectives as our goal is to highlight the effects of organizational innovation strategies on firms' technological innovation persistence. Our research, based on data derived from three waves of France's CIS, features a large and representative sample, and also provides details about the underlying dynamic mechanisms by which organizational innovation affects technological innovation persistence, using panel econometrics (versus simple cross-sectional estimates) and more complex variables for organizational innovation that can account for continuity and diversity effects. We therefore expect a positive relationship between organizational innovation and technological innovation persistence, with an impact that depends on the way organizational changes are undertaken.

Data, variables, and descriptive statistics

Data collection

The Community Innovation Survey (CIS) follows a subject approach of innovation, with the firm as the statistical unit (rather than an individual innovation), and combines census and stratified sampling methods for each wave. The stratum variables are consistently activity and size, and data collection includes both innovators and non-innovators. For statistical consistency, we draw on three successive waves of the French CIS: CIS4 (2002–2004, which we call t-2), CIS6 (2004–2006, or t-1), and CIS8 (2006–2008, or t), as provided by the French Institute of Statistics (INSEE) and collected by the Industrial Studies and Statistics Office (SESSI)[2]. These most recent surveys are homogenous in their definitions of innovation. We can thus identify the same questions that relate to product, process, and organizational innovations, although they differed in the waves prior to the 2005 CIS. For the present analysis, we merged the three survey waves such that the final data set includes only firms that responded to all three waves and exclude any that entered or exited the market during 2002–2008. The merged sample has the characteristics of a balanced panel of 1,180 manufacturing firms with 20 or more employees (see Appendix 1).

The sector composition and size distribution of the final sample does not vary substantially from one period to another. Therefore, we describe the balanced data set for 2006, an intermediate year during our study period (see Table I). More than half of the sample consists

[2] The CIS databank has been made available to two of the authors under the mandatory condition of censorship of any individual information.

of low or medium-low technology firms (according to NACE[3] classifications) operating in sectors such as plastic products, metals (12%), food, textiles, and wood (20%). The remainder of the sample features high and medium-high technology firms (40% of the total), operating in industries such as electronics, instruments, and chemicals. Regarding the size distribution, we find our sample to have a majority (66%) of medium-sized firms (250–1000 employees).

INSERT TABLE I ABOUT HERE

Variables and descriptive statistics

Dependent variables

We used three dependent variables. The CIS considers a firm to be innovative if, in a given period of time (i.e., three years prior to the survey), it introduced a new product or process. We designed dichotomous variables to measure whether the firm produced an innovation during that period, as well as to assess the type of innovation (product, process, or organization). Product innovators introduced goods or services that were 'either new or significantly improved with respect to its fundamental characteristics, technical specifications, incorporated software or other immaterial components, intended uses, or user friendliness' in the three years prior to the survey (OECD 2005). Process innovators implemented 'new techniques (…) or significantly improved production technology, new and significantly improved methods of supplying services and of delivering products' (OECD 2005).

From these definitions, to study the persistent innovation behavior of firms, we identified three types of innovators: pure product (**Only_prod)**, pure process (**Only_proc)**, and complex **(Complex)** described in Table II. For each type of innovator, we considered the repeated measure of the innovative status for CIS wave. Therefore, we have a measure of each type of innovation for periods t, t-1 and t-2 (see Tables II to IV for definitions and descriptive statistics).

INSERT TABLES II, III and IV ABOUT HERE

[3] NACE is the 'statistical classification of economic activities in the European Community', used uniformly by all member states. We classified manufacturing industries according to their global technological intensity with NACE Revision 1.1 for the t_{-2} and t_{-1} periods, whereas t was covered by NACE Revision 2, according to the Eurostat classification (http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/Annexes/hrst_st_esms_an9.pdf).

Nevertheless, the comparison of our sample with the three CIS shows that there no significant difference among the three waves with regard to the studied variables and, hence, that the surveys are comparable to each other (Tables V and VI)[4].

INSERT TABLES V and VI ABOUT HERE

Organizational innovation

The underlying hypothesis of the paper relates to the role of organizational innovation in the technological innovation process. Several measures of organizational innovation appear in previous studies examining technological innovation (Schmidt and Rammer 2007; Armbruster et al. 2008; Mothe and Nguyen-Thi 2010, 2012). Prior research has concentrated on the probability of introducing new organizational practices during a reference period and not on the impact of organizational innovation on subsequent firm technological innovation behavior. For our purposes therefore, we propose new measures of organizational innovation that can (1) handle the temporal continuity of organizational innovation and (2) examine the degree of diversity of organizational innovation. To construct the temporal continuity of organizational innovation (**ConOrg)**, we began, as a starting point, with data about organizational innovations implemented during the reference period for each wave and created the binary composite variable of organizational innovation (**Org**). The CIS2004 reported three organizational practices: (1) new or significantly changed corporate strategy, (2) advanced management techniques, and (3) major changes to organizational structure. The CIS2006 included data on four organizational practices: (1) new business practices for organizing work and procedures, (2) new knowledge management systems, (3) new methods of workplace organization, and (4) new methods of organizing external relations. We constructed four dummy variables for each practice. Finally, CIS2008 provides information about three organizational practices: (1) new business practices for organizing work and procedures, (2) new methods of workplace organization, and (3) new methods of organizing external relations.[5] The variable **Org(t)** (t - 2, t - 1) equals 1 if at least one organizational practice was implemented during t (t - 2, t - 1) and 0 otherwise.

[4] Note that compared to the CIS2008 (2006-2008) population (see Table VI), our sample shows a slight bias in favour of product innovators because the percentage of innovative firms is slightly superior in our sample (63% in our sample compared to 39% in CIS2008) to that of the CIS2008 population. This overestimation of innovative firms is quite logical and is due to the merging of three different waves (Evangelista 2000).

[5] A methodological change between the CIS2006 and CIS2008 reintegrated 'knowledge management' back into 'new business practices for organizing procedures' for CIS2008.

Subsequently, we constructed three binary variables of organizational continuity using **Org**. **D1-ConOrg** is equal to 1 if organizational innovation was adopted in t-2 and t-1 but not in t and 0 otherwise. **D2-ConOrg** is equal to 1 if organizational innovation was adopted in t, not in t-1 and t-2 and 0 otherwise. **D3-ConOrg** is equal to 1 if organizational innovation was adopted in t and t-1 but not in t-2 and 0 otherwise (see Table III).

Both indicators of organizational innovation are thus inter-temporal such that we can control for the temporal dimension of the impact of organizational innovation on firms' capacities to innovate and the dynamics of their technological innovation behavior. Although the items pertaining to diverse organizational practices are not the same across different CIS waves, this issue does not appear to be a problem for our analysis because we determine **D-ConOrg** variables on the basis of the composite organizational variable determined for each reference period.

In Table IV, we provided the descriptive statistics pertaining to the relationship between organizational continuity and the profiles of technological innovators. More than 21% of pure product innovators do introduce organizational innovation in t - 2 or t - 1 but not in t, 10% introduce organizational innovations only in t but not in t - 2 and t - 1, and 56.42% do so in t and t-1 but not in t-2.

Other explanatory variables

In addition to organizational innovations, we added several explanatory variables to our model. Prior literature suggests that the probability of innovation depends on firm characteristics and sector-specific features. For example, external and internal R&D investments per employee raise the stock of technological knowledge in firms, because R&D increases the firm's ability to capture external knowledge (Cohen and Levinthal 1990) and exerts a positive impact on the propensity to innovate (Raymond et al. 2010). We included two variables to differentiate external from internal R&D. First, **Int_RD(t-1)** represents internal R&D intensity, measured as in-house R&D expenditures divided by the number of employees for the lagged period t - 1. Second, **Ext_RD(t-1)** accounts for external R&D intensity, measured as external R&D expenditures divided by the number of employees for the lagged period t - 1[6]. Because non-innovators do not provide R&D expenses in the Community Innovation Surveys, we assumed that they have no R&D expenses (i.e., these

[6] The total amount of in-house R&D is given directly in CIS. The total amount of external R&D is a variable that we constructed from an average of three inputs: (1) the amount dedicated to the purchase of external R&D; (2) the acquisition of machinery, equipment, and software dedicated to R&D; and (3) the acquisition of external knowledge.

variables equal 0 for non-innovators). The rate of non-response is not high enough to reweight the sample. We thus chose an imputation of the null value to each of the non-responses.

Regarding firm characteristics, we introduced four variables. First, we controlled for firm size, which is a traditional determinant of innovative activities, by using four binary variables: less than 249, between 250 and 499, between 500 and 999, and more than 1000 employees. Second, we accounted for market conditions, which proxy for the geographic sales area for each firm (Peters 2008, 2009). This qualitative ordered variable ranges from 1 to 4 according to the situation of the geographic market in which the firm sells its goods and products: 1 if the market is local or regional, 2 if it is national, 3 for EU member countries, and 4 for all other countries. Most firms in our sample fall into the fourth category (70%) and approximately 15% sell their goods and services throughout the European Union. Third, we address ownership status, because firms that are part of a group may have more incentives for innovation activities through their easier access to financing (Love and Roper 2001). It is also important to control for estimations at the group level, because some firms in our sample must apply the innovation strategy adopted by their headquarters (Mairesse and Mohnen 2010). We use the variable **GP**, a binary variable that equals 1 if the firm is part of a group, to represent ownership. Most firms in our sample (approximately 80%) belong to a group. Fourth, sector controls usually involve adding dummies for each industry, but instead, to address the technological level of the industry, we control for industrial specificity with a dichotomous ordered variable (**Dumsect**), that ranges from 1 to 4 representing high-tech, medium-high-tech, medium-low–tech, and low-tech sectors (or NACE, Rev 1 at the three-digit level of aggregation).

Estimation results

Econometric results

We estimate dynamic probit random models using the approach recommended by Wooldridge (2005) to account for unobserved heterogeneity and overcome initial condition problems (Peters 2008). With this procedure, we can examine the factors that explain the dynamics of different profiles of technological innovators, taking into account different dynamic specifications of organizational innovation.

First, to gain a better understanding of the role of organizational innovation, we estimated, as a starting point, a benchmark model (Model 1) in which any organizational variables were included. Then, we estimated a set of models in with alternative measures of organizational innovation, **D1-ConOrg, D2-ConOrg**, and **D3-ConOrg** (Model 2), as explanatory variables for each of three profiles of technological innovators: pure product, pure process, and complex. The results of Model 1 and Model 2 can be found in Table VII.

INSERT TABLE VII ABOUT HERE

Regarding the benchmark model without organizational innovation (Model 1), we found that the persistence parameters of all innovators profiles are not significant. Internal and external R&D intensity variables have mixed impacts: generally, the impact is higher and significant for product innovators. We also note that the coefficient of external R&D is significant and strongly positive for both product and complex innovators. The geographic market variable has a positive and significant impact for pure product and complex innovators. Firms open to the international market which face more foreign competition, exhibit a higher probability to innovate over time compared with firms that sell products or services only in local or regional markets. We found no impact of firm size on any of the technological innovation profiles. In our model, being a large firm does not explain persistent innovation[7].

We now turn to Model 2 (Table VII), in which dynamic organizational continuity measures were inserted. The results show that the persistence parameters for all innovator profiles are still not significant when considering **D1-ConOrg**, which reflects dynamic organizational continuity only between t-2 and t-1. In contrast, the persistence parameters for both pure product and complex innovators become significant in the equations with **D2-ConOrg** and **D3-ConOrg**, reflecting organizational continuity between t-1 and t, which are more recent periods. Being a pure product or a complex innovator in the previous time period positively correlates with the probability of being pure product or complex innovators in the future[8]. The value of the estimated coefficient also indicates the strength of the

[7] In addition, the individual average of firm size (***Sizemean***) is positive and significant for pure product innovators and negative and significant for pure process innovators, which indicates substantial correlations between these variables and unobserved individual heterogeneity.

[8] In the first step, we also estimated simple models, assuming the absence of individual effects and exogenous initial conditions. The persistence parameters were positive and highly significant for all innovator profiles. However, in these unrealistic conditions, overestimation of the dependent variable is likely; the significance of the persistence parameters therefore does not mean that true persistence exists. Results are available on request.

persistence dynamic; that is, the degree of influence of past innovation on a current decision to innovate. A higher coefficient indicates a stronger persistence process. The results show that product and complex innovators are prone to be persistent, with the initial conditions having positive and highly significant effects, such that a firm's initial innovation status is strongly correlated with unobserved heterogeneity. The results in Table VII clearly show that the introduction of organizational innovation into the models changes the significance of the persistence parameters.

These results provide evidence of the indirect effect of organizational innovation with respect to our underlying hypothesis that the way organizational changes are undertaken matters. Concretely, the more recent the introduction of organizational innovation, the greater the impact it will have on the firm's capacity to innovate persistently over time. In other words, firms that have continuously implemented organizational innovation between the lagged and current periods exhibit a higher probability of being persistent in introducing product and complex innovations relative to firms that did not implement organizational innovation. This expected result is in line with the analysis of Le Bas and Poussing (2012), which highlights the crucial role of organizational innovation in generating pure product and complex innovation over time. Because the impact of other explanatory and control variables remains unchanged between Models 1 and 2, the estimation models are robust. In both cases, the innovation persistence dynamic seems to be importantly influenced by initial conditions because of the rather short time lag.

Sensitivity analysis

To verify the robustness of the results, we ran further regressions with different specifications of our main explanatory variable: organizational innovation. Hence, in addition to the temporal continuity of organizational innovation, we need to find out whether the persistence parameters of technological innovation also change when we consider the varieties of organizational innovation. Concretely, two new temporal diversity of organizational innovation variables were introduced: **DivOrg(t)** and **DivOrg(t – 1)**. Recall that **DivOrg(t)** is a proxy for the degree of organizational diversity in period t (for the period from 2006 to 2008) that takes a value ranging from 0 to 3 depending on the type of combinations of organizational practices reported in CIS2008. Thus, we can determine whether, beyond from firms' characteristics and R&D activities, the diversity of organizational practices may indirectly affect the persistence parameters.

The estimation results for **DivOrg(t)** (Model 3) are found in Table VIII. The estimated coefficients and their levels of significance are roughly the same as those reported in Models 1 and 2. The effects of the other explanatory variables, such as R&D intensity and size, are similar across the various models, such that our estimations are robust for the control variables. Therefore, we report only the estimated coefficients related to the block of the main independent variables. The results in Table VIII indicate that the persistence parameters of pure product and complex innovations are positive and strongly significant when we control for the degree of organizational diversity in the current period, all else being equal. We found that firms implementing more than two organizational practices in the current period could change the dynamics of their product innovation behaviour relative to cases in which no organizational practices are adopted (ref. Model 1, Table VII).

INSERT TABLE VIII ABOUT HERE

The interpretation of these results is twofold. First, the joint implementation of organizational practices during the current period might induce a complementary effect, in terms of management and competence profitability, that enhances firms' capacity to continue to introduce new or improved products over time. Second, product innovators generally seem to achieve higher growth rates (Colombelli, Haned and Le Bas, 2013), which enables them to devote more resources to innovation activities and which could, in turn, create a higher capacity to innovate persistently, although this effect holds only after we control for the degree of organizational diversity. As for the other innovator profiles, we observe that the persistence parameters are positive and significant for complex innovators. With regard to the impact of organizational innovation, the organizational parameters are positive and highly significant for pure product and complex innovators. The simultaneous introduction of more than one organizational practice during the three-year period t enhances firms' technological innovation capacity during this period.

Organizational diversity for period t - 1 (the period from 2004 to 2006), **DivOrg(t-1)**, is defined by the same rules as those for period t. Its construction uses information about three organizational practices constructed on the basis of CIS2006[9]: (1) new business practices for organizing procedures, (2) new methods for organizing work responsibilities and decision

[9] CIS2006 reports four organizational practices: Business practices; Knowledge Management; Work Organization and External relations. For harmonization with CIS2008, where only three organizational practices are reported, we decide to group CIS2006 Business practices and Knowledge management so that we obtain only one binary variable that we call "business practices".

making and (3) new methods for organizing external relations with other firms or public institutions. Thus, **DivOrg(t-1)** equals 0 if firms never introduce organizational practices in t - 1, 1 if they adopt one practice, 2 if they introduce two practices, and 3 if three practices are adopted[10]. Table IX reports the estimation results with **DivOrg(t-1)** (Model 4).

INSERT TABLE IX ABOUT HERE

With this organizational innovation variable, all else being equal, the pure product innovation variable is no longer persistent whereas the complex innovation variable remains persistent but with a low significance. At first glance, this result might seem contradictory considering that, conditional on the degree of organizational diversity in the current period **(DivOrg(t))** (Table VIII), the two innovator profiles were strongly persistent. Otherwise, we can also observe that the parameters of organizational innovation are still significant for pure product and complex innovations even though the coefficients are smaller than the corresponding coefficients in Model 3 with **DivOrg(t)**. Overall, these results may be explained by the effects of the lagged time returns of organizational innovation on current innovations. We found evidence that the impact level of organizational innovation on technological persistence could depend on the way it is undertaken. Indeed, we found that the more recent the organizational innovation, the stronger organizational innovation will be in shaping the persistence parameters of technological innovation.

When considering **DivOrg(t)** and **DivOrg(t-1)**, we have implicitly assumed that the greater the number of organizational practices implemented by the firm, the more important the impact that organizational innovation will have on its technological innovation dynamics. Indeed, these variables imply degree of importance in terms of the number of organizational practices. We need, however, to find out whether the hypothesis of the positive relationship between organizational innovation and technological innovation is still supported without considering the order of importance, as with **DivOrg**.

Robustness checks of results

We introduce new measures of organizational innovation defined as binary variables as an additional robustness check. Specifically, **D1_DivOrg(t)** is equal to 1 if only one practice is adopted in t and 0 otherwise. **D2_DivOrg(t)** is equal to 1 if two practices are adopted and 0

[10] We interpret DivOrg as a measure of the diversity of organizational innovation. It should depict the diversity of new practices implemented by the firm.

otherwise. **D3_DivOrg(t)** is equal to 1 if 3 practices are adopted and 0 otherwise (Model 5 is presented in Appendix 2).

As in the preceding cases with different organizational variables, we can detect an indirect effect of organizational innovation on the dynamics of technological innovation, because the persistence parameters of pure product and complex innovation become significant and positive once we have controlled for organizational innovation in the model, all else being equal (in comparison with Model 1, Table VII). Otherwise, we also observe a positive and significant direct relationship between the temporal diversity of organizational innovation and the firm's probability of introducing product and complex innovations in the current periods as **D1_DivOrg(t)**, **D2_DivOrg(t)** and **D3_DivOrg(t)** are both significant and positive for the corresponding variables.

To analyse the temporal dimension more deeply in terms of the effect of organizational diversity on the dynamics of technological innovation, we also introduced **D1_DivOrg(t-1)**, **D2_DivOrg(t-1)** and **D3_DivOrg(t-1)** (Model 6 is presented in Appendix 3).

We find a positive impact of **D2_DivOrg(t-1)** on pure product and complex innovation, but with a lower significance and a smaller coefficient. **D2_DivOrg(t-1)** and **D3_DivOrg(t-1)** are no longer significant. Again, we find that the introduction of lagged organizational innovation reduces the indirect impact of organizational diversity on technological persistence, because the persistence parameters are no longer significant for pure product innovator and have low significance for complex innovations.

Consequently, these results provide further support for the hypothesis that the joint implementation of organizational practices, relative to a case in which no organizational practices are adopted, has an important impact in terms of leading firms to innovate and enhancing their technological innovation capacity in the same period. However, there could also be a temporal dimension, in terms of returns on organizational strategies undertaken during the previous periods, on current firm likelihood of innovating and on the persistence of technological innovation.

Discussion and conclusion

With this study, we have attempted to explore the consequences of organizational innovation on the patterns of firm technological innovation persistence. This research complements previous literature by providing robust econometric evidence on the impact of organizational innovations. In doing so, we provide new insights into the relationship between non-technological and technological innovation and deepen our comprehension of the impact of organizational innovation on technological innovation persistence. Three waves of French CIS data enabled us to examine the determinants of three profiles of technological innovators, focusing on different dynamic specifications of organizational innovation. These findings enrich the learning approach to innovation persistence. Product, process, and organizational innovation exhibit strong and systematic interactions (Antonelli, Crespi and Scellato 2012). Implementing new practices or procedures, new methods of work responsibilities, and new external relations all have consequences for (or offer incentives to) the design of newly structured products or improved processes in general. Our paper makes two contributions to the economics of innovation persistence. The first important result shows the direct impact of the depth and length of organizational innovation practices on the capacity of firms to introduce new technological innovations in the present period. Specifically, we have tracked the effects of two aspects of organizational innovation: relative temporal continuity in the implementation of organizational innovation and the level of diversity in organizational practices. We find that the level of diversity in organizational practices is more significant and positively relevant. The more practices are implemented by the firm, the higher the probability that it will remain an innovator (although this pattern does not apply to pure process innovators). These results are likely due to the positive returns on past investments and the accumulation of competencies during the previous period, which enhances firms' capacities to innovate persistently in the future. This first set of results also reaffirms the existence of system effects and synergies among alternative innovations. Competencies and knowledge gained during product development processes spill over to projects designed to improve innovation processes. Conversely, innovation in processes enhances firm efficiency, which can improve capacities to introduce new goods or services (Le Bas and Poussing 2012). Thus, firms that have combined product and process innovations in the past are more likely to be prepared, in terms of innovation opportunities, competencies, and work procedures, to introduce complex innovations in the present and future. Overall, we find strong support for the hypothesis that organizational innovation plays a positive role in a firm's capacity to introduce technological innovation, in line with previous empirical studies; however, the impact depends on the way innovations are implemented.

The second important result is the indirect effect that organizational innovation practices have on technological innovation persistence. Indeed, we can observe that the parameters of persistent behavior are significant once organizational variables are accounted for. However, the results highlight that this persistence depends on the profiles of innovators. This constitutes one of the originality of our study, which proposes to introduce such distinctions between innovator profiles. We have explicitly distinguished pure product, pure process and complex (product *and* process) innovators. In line with another recent study, we find that complex innovators are more persistent (Le Bas and Poussing 2012), with this effect decreasing with time. This indirect effect can relate to the fact that firms that introduce new technological goods and services on the market reorganize production methods of production and labor organization in their firms in order to become more efficient. Additionally, if the organizational innovation took place farther back in time, its effect is weak. That is, a specific organizational innovation exerts an effect on technological innovation in the short term, leaving almost no positive propagation effects in subsequent time periods. Our results provide strong evidence that there is a positive relationship between organizational innovation and technological innovation persistence and that the way organizational innovation is introduced plays a crucial role in terms of its impact on technological innovation persistence. Indeed, the higher the number of organizational practices and the more recent the organizational innovation, the more organizational changes will shape technological innovation persistence.

Our study is not without limitations. Some limitations are linked to some methodological considerations related to the choices made by Eurostat for its innovation surveys (see Mairesse and Mohnen for a general critique of such studies). One limitation is related to the fact that the three Community Innovation surveys are not totally independent from a temporal point of view. This raises some cautions in our study on persistent innovators because the population of persistent innovators is probably overestimated (Mairesse and Mohnen 2010). This limitation is reduced in our study because the objective is not to assess the importance of innovation persistence, but the impact of organizational innovation on such persistence. Moreover, truncating firm size at the level of 20 employees, the methodology chosen by Eurostat for the French CIS, may create some selection bias. This is because definitions of size for very small firms vary between 10 and 20 employees. Moreover, because there is no unanimously accepted definition of organizational innovation in academic research (due to the recent interest in non-technological innovation), the three surveys do not use the same questions on organizational innovation. Finally, the time period we considered in our study is not very long compared to other studies on innovation persistence. This is due to the recent availability of organizational innovation practices in Community Innovation Surveys.

Future studies could go further in the study of technological and organizational innovations. Although we know that they may both help explain firm performance, we lack proper models to track the effect of different types of innovation on firm performance over time. Thus, it is necessary to expand our analysis of innovation beyond technological aspects to gain a better understanding of firm economic performance. Further research should also include qualitative, longitudinal studies that can effectively tackle the continuity and diversity aspects of organizational innovation. Moreover, an interesting avenue for research would be to study whether the adoption of new organizational methods increases productivity. By definition, technological innovation is productive but organization changes could also reduce productivity. Such an analysis could be linked to the impact of organizational innovation on R&D sunk costs because we have seen that this effect is closely related to the productivity effect of external (cooperative relationships) and internal (working procedures and organization) R&D re-structuring.

Our study provides several new insights regarding tools to support innovation policies. The extant targets of regional and national innovation policies have been product and process innovations; we show that organizational innovation is also relevant, perhaps even more. New routines and organizational practices implemented by firms not only affect their current technological innovations but also exert lasting effects on their innovation activities. Thus, organizational innovation should be a more important feature in the design of new types of public support. In addition, the interconnected nature of innovation, and of innovation dynamics and persistence, calls for a more systemic approach to innovation policies.

References

Antonelli, C., F. Crespi, and G. Scellato. 2012. Inside innovation persistence: New evidence from Italian micro-data. *Structural Change and Economic Dynamics* 23 (4): 341–53.

Antonelli, C., F. Crespi, and G. Scellato. 2013. Internal and external factors in innovation persistence. *Economics of Innovation and New Technology*, forthcoming.

Armbruster, H., A. Bikfalvib, S. Kinkela, and G. Lay. 2008. Organizational innovation: The challenge of measuring non-technical innovation in large-scale surveys. *Technovation* 28: 644–57.

Battisti, G., and P. Stoneman. 2010. How innovative are UK firms? Evidence from the CIS4 on synergies between technological and organizational innovations. *British Journal of Management* 34(1): 187–206.

Bharadwaj, S. ,and A. Menon. 2000. Making innovation happen in organizations: Individual creativity mechanisms, organizational creativity mechanisms or both. *Journal of Product Innovation Management* 17(6): 424–34.

Cohen, M.D., and D.A. Levinthal. 1990. Absorptive capacity: A new perspective on learning innovation. *Administrative Science Quarterly* 35(1): 128–52.

Colombelli, A., Haned, N., Le Bas, C. 2013. On firm growth and innovation. Some new empirical perspectives using French CIS (1992-2004). *Structural Change and Economic Dynamics* 26 : 14-26.Crossan, M., and M. Apaydin. 2010. A multi-dimensional framework of organizational innovation. *Journal of Management Studies* 47(6): 1154–91.

Daft, R.L. 1978. A dual-core model of organizational innovation. *Academy of Management Review* 21(2): 193–210.

Damanpour, F. 1991. Organizational innovation: a meta-analysis of effects of determinants and moderators. *Academy of Management Journal* 34(3): 550–90.

Damanpour, F., and D. Aravind, 2012. Managerial Innovation: Conceptions, Processes, and Antecedents, *Management and Organization Review* 8(2): 423-454.

Dougherty, D. 1992. A practice-centered model of organizational renewal through product innovation. *Strategic Management Journal* 13(1): 77–92.

Duguet, E. and Monjon, S. 2002. Les fondements microéconomiques de la persistance de l'innovation: Une analyse économétrique. *Revue Économique* 53(3): 625–36.

Evangelista, R. 2000. Sectoral Patterns of Technological Change in Services, *Economics of Innovation and New Technology* 9(3): 183–221.

Evangelista, R., and A. Vezzani. 2010. The economic impact of technological and organizational innovations. A firm-level analysis. *Research Policy* 39(10): 1253–63.

Ganter, A., and A. Hecker. 2012. Deciphering antecedents of organizational innovation. *Journal of Business Research*, available online 7 March.

Geroski, P. A., J. van Reenen, and C.F. Walters. 1997. How persistently do firms innovate? *Research Policy* 26(1): 33–48.

Gibson, C.B., and J. Birkinshaw. 2004. The antecedents, consequences, and mediating role of organizational ambidexterity. *Academy of Management Journal* 47(2): 209–26.

Grant, R.M. 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal* 17(7): 109–22.

Gumusluoğlu, L., and A. Ilsev. 2009. Transformational leadership and organizational innovation: the roles of internal and external support for innovation. *Journal of Product Innovation Management* 26(3): 264–77.

Günday, G., Ulusoy, G., Kılıç, K., and L. Alpkan. 2011. Effects of innovation types on firm performance. *International Journal of Production Economics* 133(2011): 662-676.

Hage, J.T. 1999. Organizational innovation and organizational change. *Annual Review of Sociology* 25(1): 597–622.

Hagedoorn, J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy* 31(4): 477–92.

Heckman, J.J. 1981. The incidental parameters problem and the problem of initial conditions in estimating a discrete time discrete data stochastic process. In *The structural analysis of discrete data with econometric applications*, eds. C. Manski and D. McFadden, 4, 179–95. Cambridge: MIT Press.

Jansen, J. P., F. J. Van Den Bosch, and H. W. Volberda. 2006. Exploratory Innovation, Exploitative Innovation, and Performance: Effects of Organizational Antecedents and Environmental Moderators. *Management Science* 52(11), 1661–74.

Lam, A. 2005. Organizational innovation. In *The Oxford Handbook of Innovation*, eds. Fagerberg J., Mowery D.C. and Nelson R.R., 115–147. Oxford: Oxford University Press.

Latham, W., and C. Le Bas. 2006. *The Economics of Persistent Innovation*. Berlin and New York: Springer.

Le Bas, C., and N. Poussing. 2012. *Are complex innovators more persistent than single innovators? An empirical analysis of innovation persistence drivers*. Working Paper 1201, GATE, Lyon Saint-Etienne, France, ftp://ftp.gate.cnrs.fr/RePEc/2012/1201.pdf.

Lokshin, B., A. Van Gils, and E. Bauer. 2008a. Crafting firm competencies to improve innovative performance. WP, UNU-MERIT, http://www.merit.unu.edu/publications/wppdf/2008/wp2008-009.pdf.

Lokshin B., R. Belderbos, and M. Carree. 2008b. The productivity effects of internal and external R&D: evidence from a dynamic panel data model. *Oxford Bulletin of Economics and Statistics* 70(3): 399–413.

Love, J.H., and S. Roper. 2001. Location and network effects on innovation success: evidence for UK, German and Irish manufacturing plants. *Research Policy* 30(4): 643–61.

Love, J.H., and S. Roper. 2009. Organizing the Innovation Process: Complementarities in Innovation Networking. *Industry and Innovation* 16(3), 273–90.

Mairesse, J., and P. Mohnen. 2010. Using innovations surveys for econometric analysis. NBER working paper series 15857, http://www.nber.org/papers/w15857.

Mothe, C., and S. Brion. 2012. L'influence de changements organisationnels sur le processus d'innovation. In *Le management du changement*, ed. O. Meier. Paris: Dunod.

Mothe, C., and T.U. Nguyen-Thi. 2010. The link between non technological innovations and technological innovation. *European Journal of Innovation Management* 13(3): 313–32.

Mothe, C., and T.U. Nguyen-Thi. 2012. Non-technological and technological innovations: Do services differ from manufacturing? An empirical analysis of Luxembourg firms, *International Journal of Technology Management* 57(4): 227–44.

Nelson, R. R, and S.G. Winter. 1982. *An Evolutionary Theory of Economic Change*. The Belknap Press of Harvard University Press: Cambridge.

OECD. 2005. *Oslo Manual.* 3rd Edition.

Peters, B. 2008. Persistence Effects of Innovation Activities. In *Innovation and firm performance,* ed. Peters B., 151–99. Heidelberg, New York: Physica-Verlag, Zew Economic Studies.

Peters, B. 2009. Persistence of innovation: Stylized facts and panel data evidence, *The Journal of Technology Transfer* 34(2): 226–43.

Polder, M, G.V. Leeuwen, P. Mohnen, and W. Raymond. 2010. *Product, process and organizational innovation: drivers, complementarity and productivity effects*, United Nations University - Maastricht Economic and social Research and training centre on Innovation and Technology, Maastricht, The Netherlands.

Raymond, W., P. Mohnen, F.C. Palm, and S. Schim Van Der Loeff. 2010. Persistence of innovation in Dutch manufacturing: Is it spurious? *Review of Economics and Statistics* 92(3): 495–504.

Sapprasert, K., and T. Clausen. 2012. Organizational innovation and its effects. *Industrial and Corporate Change* 21(5): 1283–1305.

Schmidt, T., and C. Rammer. 2007. *Non-technological and technological innovation: strange bedfellows?* Working Paper 07-052, ZEW, ftp://ftp.zew.de/pub/zew-docs/dp/dp07052.pdf.

Tatikonda, M.V., and M.M. Montoya-Weiss. 2001. Integrating operations and marketing perspectives of product innovation: the influence of organizational process factors and capabilities on development performance. *Management Science* 47(1): 151–72.

Teece, D.J. 1988. Technological change and the nature of the firm. In *Technical Change and Economic Theory*, eds. G. Dosi, C. Freeman, R. Nelson, G. Silverberg and Soete L., 256–77. New York: Pinter Publishers.

Teece, D.J. 1992. Competition, Cooperation, and Innovation: Organizational Arrangements for Regimes of Rapid Technological Progress. *Journal of Economic Behavior and Organization*, 18(1): 1–25.

Teece, D.J. 1998. Design issues for Innovative Firms: Bureaucracy, Incentives and Industrial Structure. In *The Dynamic Firm*, eds. Chandler A.D., Hagström Jr., P. and Sölvell O., 135–65. Oxford: Oxford University Press.

Tushman, M., W. K. Smith, R. Wood, G. Westerman, and C. O'Reilly. 2010. Organizational designs and innovation streams. *Industrial & Corporate Change* 19(5): 1331–66.

Un, C., A. Cuervo-Cazurra, and K. Asakawa, 2010. R&D Collaborations and Product Innovation. *Journal of Product Innovation Management*, 27(5): 673–89.

Verona, G., and D. Ravasi, 2003. Unbundling Dynamic Capabilities: an Exploratory Study of Continuous Product Innovation. *Industrial and Corporate Change* 12 (3): 577–606.

Wernerfelt, B. 1984. A resource-based view of the firm. *Strategic Management Journal* 5(2): 171–80.

Wooldridge, J.M. 2005. Simple solutions to the initial conditions problem in dynamic nonlinear panel data models with unobserved heterogeneity. *Journal of Applied Econometrics* 20(1): 39–54.

Wu, X., R. Ma, and G. Xu. 2009. Accelerating Secondary Innovation through Organizational Learning: A Case Study and Theoretical Analysis. *Industry and Innovation* 16(4): 389–409.

Table I. Sectoral composition, technological intensity and size distribution – 2006

Sectors of activity	NACE Rev 1.1	Number	Percentage
Pharmaceuticals	24.41-24.42	47	3.98
Computers, office machinery and electronics-communication	30 and 32	30	2.54
Medical, precision, and optical instruments, watches and clocks	33	22	1.86
Aerospace	35.3	27	2.29
Chemicals	24 (excluding 24.41 and 24.42)	92	7.80
Machinery and equipment	29	106	8.98
Electrical machinery	31	72	6.10
Motor vehicles and transport equipment	34-35 (excluding 35.1 and 35.3)	99	8.39
Petroleum refining	23	10	0.85
Rubber and plastic products and other non-metallic mineral products	25-26	146	12.37
Metals	27-28	133	11.27
Shipbuilding	35.1	4	0.34
Other manufacturing	36.2-36.6	29	2.46
Food	15	194	16.44
Textiles	17-19	59	5.00
Wood, paper and furniture	20-21 and 36.1	88	7.46
Printing and reproduction of recorded media	22 (excluding 22.3)	22	1.86
Total		**1180**	**100**
Technological intensity			
Low-technology		363	30.76
Medium low-technology		322	27.29
Medium high-technology		369	31.27
High-technology		126	10.68
Total		**1180**	**100**
Size class			
Size <=249		208	17.63
Size 250-499		520	44.07
Size 500-999		266	22.54
Size >= 1000		186	15.76
Total		**1180**	**100**

Table II. Variables

Variables	Type	Description
		Alternative endogenous variables of innovation performance indicators all displayed for the year 2008 (present period, t)
Only_prod	B	Equals 1 for firms that are "pure product innovators": this category includes the firms that introduce a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems
Only_proc	B	Equal 1 for firms that are "pure process innovators": this category includes firms that at least one type of one of the three process innovations regarding any new or significantly improved (1) methods of manufacturing or producing goods or services (2) logistics, delivery or distribution methods for your inputs, goods or services (3) supporting activities for your processes, such as maintenance, systems or operations for purchasing, accounting, or computing
Complex	B	Equals 1 for firms that have introduced both product and process innovations

		Varying across individuals and time
		Organizational innovation (several variables) and R&D expenses
D1_ConOrg	B	Equal to 1 if organizational innovation was adopted in t-2 and t-1 but not in t; 0 otherwise
D2_ConOrg	B	Equal to 1 if organizational innovation was adopted only in t, but not in t-2 and t-1; 0 otherwise
D3_ConOrg	B	Equal to 1 if organizational innovation was adopted in t and t-1 but not in t-2; 0 otherwise
DivOrg(t)	DO	Equal 0 if none of the organizational practices was adopted in t; 1 if only one practice was adopted; 2 if two practices were adopted; and 3 if both three practices were adopted
DivOrg(t-1)	DO	Equal 0 if firms did not introduce any organizational practices in t-1; 1 if only one practice was adopted; 2 if only two practices were adopted; 3 if 3 practices were adopted and 4 if all practices were adopted.
D1_DivOrg(t)	B	Equal to 1 if only one organizational practice was adopted in t; 0 otherwise
D2_DivOrg(t)	B	Equal to 1 if two organizational practices were adopted in t; 0 otherwise
D3_DivOrg(t)	B	Equal to 1 if three organizational practices were adopted in t; 0 otherwise
Int_RD(t-1)	Q	Internal R&D expenses (estimated amount of expenditures for in-house R&D that includes capital expenditures on buildings and equipment specifically dedicated to R&D) divided by the total number of employees for the year 2006.
Ext_RD(t-1)	Q	External R&D expenses (average of three CIS variables: (1) the amount dedicated to the purchase of external R&D, (2) the acquisition of acquisition of machinery, equipment and software - that exclude expenditures on equipment for R&D- and (3) the acquisition of external knowledge) divided by the number of employees for the year 2006.

Firm characteristics, year 2008 (present, period t)		
Size <=249	B	Firms having less than 250 employees
Size 250-499	B	Firms having between 250 and 499 employees
Size 500-999	B	Firms having between 500 and 999 employees
Size >= 1000	B	Firms having more than 1000 employees
$Market_t$	DO	Ranging from 1 to 4 according the situation of the geographic market where the enterprise sells its goods and products: 1 if the market is local or regional, 2 if it is national, 3 if it concerns EU member countries, 4 for all other countries.
Gp_t	B	Equals 1 if the firm is part of a group
$Dumsect_t$	DO	Score ranging from 1 to 4 to reflect the technological intensity of sectors, based on NACE Rev 1.1 at three-digit level for compiling aggregates: 1 for high-technological activities that include pharmaceuticals, computers, office machinery, electronics and communication, medical, precision, and optical instruments, watches and clocks and aerospace; 2 for medium-high technological activities that include chemicals, machinery and equipment, electrical machinery, motor vehicles and transport equipment; 3 for medium-low technological activities that include petroleum refining, rubber and plastic products and other non-metallic mineral products, metals, shipbuilding and other manufacturing activities; 4 for low-technological activities that include food, textiles, wood, paper and furniture and printing and reproduction of recorded media.
Variables measuring individual heterogeneity (time averages of explanatory variables)		
	Q	MGp; MDumsect; MSize; MGeomarket

Notes: B indicates binary, DO dichotomous ordered variable, and Q indicates quantitative variables.

Table III. Summary statistics

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Dependent variables					
Only_prod	1180	0,63	0,483	0	1
Only_proc	1180	0,10	0,302	0	1
Complex	1180	0.49	0.50	0	1
Organizational variables					
D1_ConOrg	1180	0.25	0.44	0	1
D2_ConOrg	1180	0.11	0.32	0	1
D3_ConOrg	1180	0.45	0.50	0	1
IntOrg(t)	1180	1.11	1.13	0	3
IntOrg(t-1)	1180	1.60	1.38	0	4
D1_DivOrg	1180	0.23	0.42	0	1
D2_DivOrg	1180	0.24	0.43	0	1
D3_DivOrg	1180	0.14	0.36	0	1
Explanatory variables					
Int_RD(t-1)	1180	4.90	12.333	0	167.310
Ext_RD(t-1)	1180	1.96	6.896	0	91.767
Size <=249	1180	0.17	0.38	0	1
Size 250-499	1180	0.43	0.49	0	1
Size 500-999	1180	0.22	0.42	0	1
Size >= 1000	1180	0.16	0.37	0	1
Geomarket	1180	3.624	0.736	1	4
GP	1180	0.887	0.316	0	1
Dumsect	1180	2.761	1.025	1	4

Table IV. Descriptive statistics for technological and organizational innovations (%)

	Values	*Only_Prod(t)*	*Only_Proc(t)*	*Complex(t)*
D1_ConOrg	1	21.52	26.67	16.50
D2_ConOrg	1	10.03	15.00	10.03
D3_ConOrg	1	56.42	42.50	63.61
DivOrg(t-1)	0	30.11	32.56	19.90
	1	19.56	18.44	17.18
	2	20.83	22.64	24.15
	3	18.60	14.00	23.64
	4	11.00	12.36	15.14
		100	*100*	*100*
DivOrg(t)	0	33.56	42.50	26.36
	1	17.11	18.33	16.33
	2	27.67	27.50	31.46
	3	21.66	11.67	25.85
		100	*100*	
D1_DivOrg	1	17.11	18.33	16.33
D2_DivOrg	1	27.67	27.50	31.46
D3_DivOrg	1	21.66	11.67	25.85
Observations		*748*	*120*	*588*

Table V. A comparison between CIS2006 population and the empirical sample

Number of innovative firms	**Sample**	**Cis2008 (2006-2008)**
Only_prod	63%	27%
Only_proc	10%	11%
Complex	51%	27%

Table VI. Descriptive statistics: CIS 2002-2004, 2004-2006 and 2006-2008

	CIS4				**CIS2006**				**CIS2008**			
	Mean	***std***	***Min***	***Max***	***Mean***	***std***	***Min***	***Max***	***Mean***	***std***	***Min***	***Max***
Pure product innovators	0,39	0,49	0	1	0,44	0,49	0	1	0,39	0,49	0	1
Pure process innovators	0,13	0,34	0	1	0,11	0,30	0	1	0,11	0,32	0	1
Complex innovators	0.29	0.45	0	1	0,31	0,46	0	1	0,27	0,45	0	1
Internal R&D	3,07	21,46	0	1000	3,03	17,3	0	899,38	2,84	14,53	0	638,79
External R&D	2,96	105,93	0	8861,54	1,46	7,7	0	193,5	2,31	10,21	0	348,26
Part of a Group	0,59	0,49	0	1	0,63	0,48	0	1	0,5	0,5	0	1
Geomarket	3,05	1,07	1	4	3,17	1,02	1	4	2,9	1,13	1	4

Table VII: Dynamic RE Probit estimation to innovate in function of "organizational continuity" (model 2)

	Model 1: benchmark			*Model 2*		
	Only_Prod	***Only_Proc***	***Complex***	***Only_Prod***	***Only_Proc***	***Complex***
Lagged innovation						
Only_prod(t-1)	0.233(0.178)			0.268(0.180)		
Only_proc(t-1)		0.164(0.220)			0.148(0.220)	
Complex(t-1)			0.254(0.157)			0.246(0.160)
Organizational continuity						
D1-ConOrg				0.092(0.130)	0.221(0.158)	0.136(0.127)
D2-ConOrg				0.695(0.136)***	0.415(0.161)***	0.939(0.134)***
D3-ConOrg				0.871(0.142)***	0.231(0.145)	1.051(0.141)***
Other explanatory variables						
Internal R&D	0.005(0.003)*	0.008(0.005)	0.001(0.002)	0.006(0.003)**	0.008(0.005)	0.001(0.002)
External R&D	0.0231(0.007)***	-0.009(0.006)	0.016(0.006)***	0.022(0.007)***	-0.008(0.00615)	0.016(0.006)**
Gp	0.170(0.280)	0.333(0.333)	0.327(0.251)	0.189(0.282)	0.396(0.335)	0.335(0.255)
Sectors dummy	-0.156(0.208)	0.237(0.274)	-0.208(0.187)	-0.244(0.212)	0.227(0.275)	-0.293(0.191)
Size 250-499	-0.120(0.451)	1.088(0.560)*	-0.194(0.406)	-0.176(0.461)	1.153(0.571)**	-0.257(0.425)
Size 500-999	0.247(0.547)	0.609(0.665)	-0.216(0.486)	0.218(0.556)	0.649(0.676)	-0.286(0.504)
Size >= 1000	-0.468(0.713)	0.589(0.871)	-0.522(0.620)	-0.455(0.717)	0.682(0.882)	-0.506(0.640)
Geomarket	0.218(0.106)**	0.174(0.129)	0.209(0.097)**	0.212(0.108)*	0.167(0.131)	0.204(0.101)**
Initial conditions						
Only_prod(0)	1.207(0.230)***			1.114(0.226)***		
Only_proc(0)		0.825(0.240)***			0.841(0.242)***	
Complex(0)			0.842(0.178)***			0.751(0.171)***
Gpmean	0.243(0.318)	-0.154(0.364)	0.0410(0.286)	0.211(0.320)	-0.212(0.366)	0.021(0.289)
Dumsectmean	-0.0189(0.213)	-0.193(0.278)	0.109(0.191)	0.107(0.217)	-0.179(0.279)	0.238(0.195)
Size250-499mean	0.471(0.474)	-1.309(0.578)**	0.552(0.427)	0.530(0.484)	-1.395(0.590)**	0.624(0.446)
Size500-999mean	0.521(0.578)	-0.735(0.678)	0.933(0.512)*	0.485(0.585)	-0.800(0.689)	0.945(0.529)*
Size1000mean	1.423(0.752)*	-1.237(0.898)	1.582(0.654)**	1.344(0.754)*	-1.351(0.910)	1.524(0.673)**
Geomarketmean	0.092(0.127)	-0.233(0.145)	0.033(0.113)	0.047(0.127)	-0.235(0.147)	-0.009(0.116)
Int_RDmean	0.006(0.005)	-0.018(0.010)*	-0.001(0.003)	0.005(0.004)	-0.0191(0.010)*	-0.001(0.003)
Ext_RDmean	-0.021(0.010)**	0.033(0.010)***	-0.008(0.008)	-0.025(0.011)**	0.034(0.010)***	-0.011(0.009)
Constant	-1.854(0.332)***	-1.652(0.351)***	-1.968(0.296)***	-2.226(0.353)***	-1.858(0.379)***	-2.517(0.331)***
ρ	0.434(0.088)	0.335(0.119)	0.311(0.093)	0.407(0.093)	0.350(0.117)	0.278(0.097)
-2lnL	1108.43	629.34	1297.24	1063.30	688.73	1211.56
Percent correctly predicted	82.8	72.7	78.9	84.5	72.8	81.0
Observations	2360	2360	2360	2360	2360	2360

*Notes : *, ** and *** denote significance at the levels of 10%, 5% and 1%. Standard errors in parentheses. Random effects estimates are computed by adaptative Gausse-Hermite quadrature.*

Table VIII : Dynamic RE Probit estimations to innovate in function of "organizational diversity" in period t (Model 3)

	Only_Prod	***Only_Proc***	***Complex***
Lagged innovation			
Only_prod(t-1)	0.343(0.173)**		
Only_proc(t-1)		0.167(0.219)	
Complex(t-1)			0.403(0.144)***
Organizational diversity			
DivOrg(t)	0.287(0.035)***	0.025(0.037)	0.364(0.032)***
Other explanatory variables			
Internal R&D	0.006(0.002)**	0.008(0.005)	0.001(0.002)
External R&D	0.021(0.007)***	-0.009(0.006)	0.014(0.006)**
Gp	0.203(0.276)	0.343(0.333)	0.381(0.247)
Dumsect	-0.211(0.210)	0.233(0.274)	-0.265(0.188)
Size 250-499	-0.142(0.452)	1.090(0.561)*	-0.212(0.409)
Size 500-999	0.215(0.548)	0.605(0.665)	-0.291(0.488)
Size >= 1000	-0.373(0.708)	0.598(0.872)	-0.406(0.621)
Geomarket	0.218(0.106)**	0.173(0.129)	0.201(0.097)**
Initial conditions			
Only_prod(0)	1.020(0.218)***		
Only_proc(0)		0.823(0.240)***	
Complex(0)			0.583(0.156)***
Gpmean	0.185(0.310)	-0.165(0.365)	-0.057(0.275)
Dumsectmean	0.0797(0.215)	-0.185(0.278)	0.225(0.191)
Size250-499mean	0.473(0.473)	-1.314(0.579)**	0.547(0.425)
Size500-999mean	0.455(0.574)	-0.738(0.678)	0.880(0.510)*
Size1000mean	1.191(0.741)	-1.258(0.900)	1.287(0.648)**
Geomarketmean	0.047(0.124)	-0.235(0.145)	-0.010(0.110)
Int_RDmean	0.004(0.004)	-0.018(0.010)*	-0.002(0.003)
Ext_RDmean	-0.024(0.011)**	0.033(0.010)***	-0.011(0.009)
Constant	-2.067(0.323)***	-1.680(0.355)***	-2.259(0.282)***
ρ	0.360(0.098)	0.335(0.119)	0.159(0.103)
-2lnL	1067.23	692.11	1199.65
Percent correctly predicted	84.6	72.6	82.8
Observations	2360	2360	2360

*Notes : *, ** and *** denote significance at the levels of 10%, 5% and 1%. Standard errors in parentheses. Random effects estimates are computed by adaptative Gausse-Hermite quadrature.*

Table IX: Dynamic RE Probit estimation to innovate in function of "organizational diversity" in period t-1 (Model 4)

	Only_Prod	*Only_Proc*	*Complex*
Lagged innovation			
Only_prod(t-1)	0.240(0.177)		
Only_proc(t-1)		0.165(0.220)	
Complex(t-1)			0.270(0.157)*
Organizational diversity			
DivOrg(t-1)	0.072(0.033)**	-0.0102(0.038)	0.071(0.028)**
Other explanatory variables			
Internal R&D	0.005(0.003)*	0.008(0.005)	0.001(0.002)
External R&D	0.022(0.007)***	-0.009(0.006)	0.016(0.006)**
Gp	0.145(0.277)	0.339(0.334)	0.308(0.248)
Dumsect	-0.145(0.206)	0.236(0.274)	-0.205(0.184)
Size 250-499	-0.128(0.446)	1.091(0.560)*	-0.195(0.401)
Size 500-999	0.258(0.542)	0.607(0.664)	-0.190(0.480)
Size >= 1000	-0.469(0.708)	0.590(0.871)	-0.510(0.613)
Geomarket	0.219(0.105)**	0.173(0.129)	0.208(0.096)**
Initial conditions			
Only_prod(0)	1.154(0.226)***		
Only_proc(0)		0.825(0.240)***	
Complex(0)			0.768(0.177)***
Gpmean	0.263(0.315)	-0.160(0.365)	
Dumsectmean	-0.015(0.211)	-0.194(0.278)	0.048(0.281)
Size250-499mean	0.474(0.469)	-1.311(0.578)**	0.122(0.188)
Size500-999mean	0.480(0.572)	-0.731(0.677)	0.544(0.420)
Size1000mean	1.373(0.746)*	-1.232(0.898)	0.869(0.504)*
Geomarketmean	0.078(0.125)	-0.231(0.145)	1.505(0.646)**
Int_RDmean	0.006(0.005)	-0.018(0.010)*	0.019(0.111)
Ext_RDmean	-0.021(0.010)**	0.033(0.010)***	-0.001(0.003)
Constant	-1.897(0.326)***	-1.641(0.353)***	-0.008(0.008)
ρ	0.410(0.091)	0.335(0.119)	0.265(0.099)
-2lnL	1106.13	692.30	1294.23
Percent correctly predicted	83.0	72.8	79.0
Observations	2360	2360	2360

*Notes : *, ** and *** denote significance at the levels of 10%, 5% and 1%. Standard errors in parentheses. Random effects estimates are computed by adaptative Gausse-Hermite quadrature.*

Appendix I. The structure of the final panel

year	Time	$Only\_prod_t$ $Only\_proc_t$ $Complex_t$	Number of observations	$Only\_prod_{t-1}$ $Only\_proc_{t-1}$ $Complex_{t-1}$	Number of observations
2002-2004	t-2	I_0	1180	.	
2004-2006	t-1	I_1	1180	I_0	2360
2006-2008	t	I_2	1180	I_1	2360

Appendix II. Dynamic RE Probit estimation to innovate in function of “organization intensity” in period t (Model 5)

	Only_Prod	*Only_Proc*	*Complex*
Lagged innovation			
Only_prod(t-1)	0.349(0.170)**		
Only_proc(t-1)		0.170(0.218)	
Complex(t-1)			0.380(0.143)***
Organizational diversity			
D1_DivOrg(t)	0.609(0.106)***	0.148(0.123)	0.580(0.093)***
D2_DivOrg(t)	0.718(0.106)***	0.322(0.119)***	0.968(0.097)***
D3_DivOrg(t)	0.994(0.139)***	-0.138(0.155)	1.237(0.123)***
ρ	0.364(0.096)	0.343(0.118)	0.178(0.100)
-2lnL	1060.68	686.24	1192.90
Percent correctly predicted	84.8	72.7	82.9
Observations	2360	2360	2360

*Notes : *, ** and *** denote significance at the levels of 10%, 5% and 1%. Standard errors in parentheses. Random effects estimates are computed by adaptative Gausse-Hermite quadrature.*

Appendix III. Dynamic RE Probit estimation to innovate in function of “organization intensity” in period t-1 (Model 6)

	Only_Prod	*Only_Proc*	*Complex*
Lagged innovation			
Only_prod(t-1)	0.249(0.179)		
Only_proc(t-1)		0.181(0.219)	
Complex(t-1)			0.268(0.160)*
Organizational diversity			
D1_DivOrg(t-1)	0.059(0.098)	0.038(0.115)	0.054(0.086)
D2_DivOrg(t-1)	0.274(0.106)**	-0.116(0.127)	0.264(0.091)***
D3_DivOrg(t-1)	0.171(0.134)	0.074(0.152)	0.216(0.112)*
ρ	0.406(0.092)	0.336(0.119)	0.262(0.101)
-2lnL	1104.81	691.32	1292.23
Percent correctly predicted	83.1	72.5	79.1
Observations	2360	2360	2360

*Notes: *, ** and *** denote significance at the levels of 10%, 5% and 1%. Standard errors in parentheses. Random effects estimates are computed by adaptative Gausse-Hermite quadrature.*