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Learning Modes, Types of Innovation and Economic Performance

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Abstract

This contribution focuses on a current heated debate on learning modes employed by the firms, and their impact on innovation and economic output. The interactive approach developed by the Scandinavian school on innovation systems characterized two key learning modes as ‘science and technology-based innovation’ (STI) and ‘learning-by-doing, by-using and by-interacting-based innovation (DUI). This work analyzes first the separate and combined impact of such modes of learning and innovation on two types of innovation output: product and process. In this operation, this work produces interesting and challenging results. Moreover, this paper offers the original hypothesis that these learning modes have a differentiated impact on product and process innovation. Simultaneously, this contribution adds a further analytical element, which is the explicit connection to the capacity of firms to transform innovation output (product and process) in economic performance. A two-stage mode is formulated and applied in the context of an extensive database of Spanish manufacturing and service firms (PITEC). This allows implementing an original time-series analysis that leads to obtaining insightful results that question former analyses and might heat further the debate on the most effective learning and innovation modes applied by firms as a means to gain competitiveness in open markets.

Resumen

Este trabajo se enfoca en el debate académico actual sobre los modos de innovación adoptados por las empresas y su impacto sobre el resultado de innovación y el desempeño económico. El enfoque desarrollado por la escuela escandinava sobre sistemas de innovación caracteriza dos modos de aprendizaje e innovación: el primero, basado en la gestión en “ciencia y tecnología” (STI), y el segundo, basado en “aprender haciendo, utilizando e interactuando” (DUI). Este trabajo analiza, primero, el impacto separado y combinado de estos modos de aprendizaje e innovación sobre dos tipos de resultados de innovación: producto y proceso. En este sentido, el trabajo ofrece resultados interesantes y cruciales que dan apoyo a la hipótesis original de que estos modos de aprendizaje tienen un impacto diferenciado sobre la innovación de producto y proceso. Esto supone que el uso combinado de ambos modos de aprendizaje no necesariamente está relacionado con una mayor probabilidad de innovar como sugieren estudios anteriores que analizan los resultados de innovación general, sino que de manera específica el modo de aprendizaje basado en STI está más relacionado con la innovación de producto, mientras que el modo de aprendizaje basado en DUI está más relacionado con la innovación en procesos. Al mismo tiempo, esta contribución va más allá al analizar la capacidad de las empresas para transformar el resultado de innovación (producto y proceso) en el desempeño económico. Este análisis en dos etapas se realiza en el contexto de una extensa base de datos longitudinal que recoge información de las actividades de innovación de empresas españolas de la industria manufacturera y de servicios (PITEC). Esto permite implementar un análisis de panel con el que se obtienen resultados que cuestionan estudios anteriores y que contribuyen al debate sobre los modos más eficaces de innovación aplicados por las empresas como medio para alcanzar una mayor competitividad en mercados abiertos.

Laburpena

Ekarpena enpresen berritzeko moduen eta horrek berrikuntza eta ekonomia emaitzetan dituen eraginen inguruko gaur egungo eztabaida akademikoan kokatzen da. Berrikuntza sistemei buruz Eskandinaviako eskolak proposatutako ikuspegiak ikasteko eta berritzeko bi modu bereizten ditu: lehenengoa, ‘zientzia eta teknologiaren’ kudeaketan oinarritzen dena (STI) eta, bigarrena, ‘ekinez, erabiliz eta elkar eraginez ikastean' (DUI) oinarritzen dena. Lan honetan ikasteko eta berritzeko bi modu horien eragina aztertu nahi dugu, lehenengo bereizita eta ondoren elkarrekin, berrikuntzaren bi emaitzetan: produktua eta prozesua. Hain zuzen ere, lanak emaitza interesgarri eta garrantzitsuak eskaintzen dizkigu, hasierako hipotesia berresteko: bi ikaskuntza moduek nork bere eragina du produktuaren eta prozesuaren berrikuntzan. Horrenbestez, ikasteko bi moduen erabilera konbinatuak ez dakar, ezinbestean berritzeko probabilitatea handitzea, berrikuntza orokorraren emaitzei buruz lehendik egindako azterlanek iradokitzen zuten bezala. Aitzitik, zientzian eta teknologian oinarritutako ikasteko moduak lotura estuagoa du produktuaren berrikuntzarekin, eta DUI ikasteko moduak lotura estuagoa du prozesuetako berrikuntzarekin. Gainera, azterlanak beste ekarpen bat ere egiten du, enpresek berrikuntzaren (produktukoa eta prozesukoa) emaitza emaitza ekonomiko bihurtzeko gaitasuna ere aztertzen baitu. Bi etapetako analisi horretarako luzeratako datu base zabal bat erabili da, manufakturako eta zerbitzuetako Espainiako enpresen berrikuntzako jardueren inguruko informazioa jasotzen duena. Horrek aukera ematen du paneleko analisia egiteko. Lortutako emaitzek aurreko azterlanen emaitzak zalantzan jartzen dituzte eta enpresentzat berrikuntza modurik eraginkorrenen inguruko eztabaidari lagundu nahi diote, merkatu irekietan lehiakortasun handiagoa lortzeko bitarteko baitira.

"Innovation distinguishes between a leader and a follower". Steve Jobs

1 Introduction

For several years, numerous studies have linked the concepts of innovation and economic growth. A large bulk of these studies conducted by well-known researchers has highlighted the role played by National Innovation Systems (NIS) and Regional Innovation Systems (RIS) to spur economic development (Cooke & Morgan, 1996; Lundvall, 1992; Nelson, 1993). Most authors agree that innovation has become *a sine qua non* condition to advance through different economic stages (i.e., factor-driven, efficiency-driven and knowledge-driven economies). Certainly, innovation and entrepreneurship are important drivers of growth (Audretsch & Keilbach, 2008; González-Pernía, Peña-Legazkue, & Vendrell-Herrero, 2012), but regions and countries do not innovate *per se*. Rather, people representing enterprises and institutions undertake innovation-driven (economic) activities.

There is a large amount of literature describing the determinants and the impact of innovation at the firm level (Greve, 2003; Stam & Wennberg, 2009; Thornhill, 2006). Yet, our understanding is not deep enough as to explain with certainty the whole process by which firm innovation translates into economic value. The answer to this difficult, but important, concern has remained ambiguous and unclear for some decades. We propose a *holistic view* to respond to this issue. The main objective of this article is precisely to disentangle the different components of the firm "innovation black box" by shedding some light on the complex linkages between learning modes (i.e., STI –Science, Technology and Innovation-, and DUI –Doing, Using and Interacting- modes), innovation types (i.e., product/process innovation) and the broader innovation effects (i.e., firm performance). Departing from the definition by Hemert, Nijkamp, & Masurel (2012), where firm innovation is understood as "an interactive process that involves the generation, adoption, implementation, and incorporation of new ideas and practices" -within and out of the firm, and with the aim of yielding economic value-, we attempt to conduct an empirical study to test our comprehensive model which includes the aforementioned relationships among firm learning modes, innovation types and performance.

Overall, we expect to contribute to the extant literature at least in three ways. Firstly, our conjecture is that different configurations of STI and DUI practices[1] in the form of internal and external firm relationships exert a different effect on product innovation and process innovation behavior. Secondly, prior studies have examined both product and process innovation effects on firm performance (Evangelista & Vezzani, 2010), but these studies have analyzed the subject under a static view. The literature lacks research which explores the linkage of innovation types and performance from a "dynamic" perspective (Davidsson & Wiklund, 2000). Our study addresses this inter-temporal phenomenon through panel regression tests. And thirdly, our work goes beyond one-region one-period type of analysis, as we examine firms from multiple-regions and multiple-periods accounting for spatial and temporal heterogeneity.

The paper is structured as follows. In section 2, we explain the foundations of our broad model where learning modes, innovation types and firm performance are explained. In section 3, we describe the data and methods used for our empirical work. Results are discussed in section 4, and the study ends with main conclusions and implications.

2 Innovation modes, types and effects

2.1 STI and DUI learning modes under a regional perspective

For many years, the importance of R&D expenditure, S&T infrastructures, and human capital have been identified as the core drivers to innovation in advanced -economies (Cohen & Levinthal, 1989; Greunz, 2005; Griliches, 1979; Nelson, 1993). Notwithstanding this general agreement, some scholars identified advanced countries that produced a very good innovation and economic performance in spite of the relatively lower investments in R&D and infrastructures. It was the case of Denmark and Norway, in the North of Europe (Gertler & Asheim, 2006), and of specific regions in the south of Europe (e.g. the Centre-North in Italy), which generated a good innovation output and economic performance on the basis of a different set of innovation drivers (Becattini, Bellandi, & Propris, 2009; Parrilli & Asheim, 2012). The intuition suggested by Adam Smith long ago, then re-developed by Arrow (1962), on the increase in productivity due to learning-by-doing partly explain such a good innovation and economic performance. This approach has been developed by Lundvall and other scholars by extending this approach to include the interactive driver as a key means to co-generate and transfer relevant knowledge within the organization (Kline & Rosenberg, 1986) and among firms and organizations (Lundvall, 1992).

This more complete view of innovation has responded to the so-called 'innovation paradox' that was identified in those countries where most firms did not produce an innovation output (e.g. publications, patents, new products, new designs) corresponding to the volume of classic knowledge and innovation inputs that are introduced in the company (e.g. R&D expenditure, infrastructures, human capital) in comparison to firms operating in other countries in similar competitive conditions. For example, Swedish companies (and the country as a whole) have long been considered stuck in an innovation paradox vis-à-vis firms in countries such as Norway and Denmark that invested comparatively less on such inputs. The novelty of the theoretical debate on the importance of interactive- and practice-based learning helps to explain the high effectiveness of the latter firms and countries that would otherwise be incomprehensible on the basis of STI inputs alone.

The STI learning mode contributes to the generation of advanced scientific and technological knowledge, mainly associated to analytical processes driven to identify natural principles and mechanisms that can be applied to all firms and in industries with a preference for chemicals, pharmaceuticals, biotechnology and nanomaterials; the DUI approach alone adds the possibility of learning-by-doing, by-using and by-interacting that promote the translation of scientific, analytical knowledge inputs into synthetic and symbolic knowledge that more easily delivers outputs that are utilized in engineering-based businesses and in industries such as machine-tools and automotive, shipbuilding, as well as many traditional manufacturing sectors (Asheim & Coenen, 2005). The combination of the two (STI+DUI) is expected to merge the strength of the first type of knowledge flow with the second in a way that generates more scientific knowledge output and, simultaneously, catalyze stronger business interactions that enrich the knowledge output with adaptations and transformations that also represent business innovations.

Such ideal approach has been analyzed in other geographical contexts, such as China (Chen, Chen, & Vanhaverbeke, 2011), Scandinavian countries (mainly Norway; see (Aslesen, Isaksen, & Karlsen, n.d.; Dahl Fitjar & Rodríguez-Pose, 2011; Isaksen &

Karlsen, 2010), and Spain (Parrilli & Elola, 2011). With few exceptions in mind (Parrilli & Elola, 2011), the results support that both drivers seem to contribute positively to innovation output.

2.2 The impact of STI and DUI modes on process and product innovation

We expect that the STI learning mode has a more direct effect on product innovation as its core activity (R&D) tends to discover and test new product properties, qualities, configurations, whereas the DUI learning mode tends to focus more directly on process innovation through exchanges and interactions among workers or among managers and clients, suppliers and service providers in order to improve the way activities are developed. These hypotheses reflect the propensity of R&D activities to focus on discovering new products (e.g. new drugs, materials, types and models of aircrafts and vehicles) whereas learning by-doing and by-using have a propensity to produce new engineering processes and organizing methods (e.g. reorganization of plant layout, speed in product delivery, efficient use of resources). Additionally, in the short term we expect to have a stronger impact on process innovation (improvements and productivity) whereas in the longer term product innovations are also expected as time is available to make changes in work routines (e.g. making new molds to incorporate new components and systems in assembly operations).

Hypothesis 1a: STI and DUI modes taken separately exert a positive effect on both product and process innovation.

Hypothesis 1b: While the STI mode has a stronger effect on product innovation, the DUI mode has a stronger effect on process innovation

Hypothesis 1c: The combined STI+DUI innovation mode does not add a relevant value/impact on both process and product innovation.

If hypothesis 1a calls for a wide consensus based on several old (Griliches, 1979; Greunz, 2005) and new studies (Jensen et al., 2007), it is hypothesis 1b and 1c that represent rather novel contributions. In fact, hypothesis 1b is developed according to the former argument, whereas hypothesis 1c contrasts rather directly previous contributions that prove a positive and significant effect of the combination between the STI and the DUI approaches (Jensen et al., 2007; Chen et al., 2010; Aslesen et al., 2011). Also on the basis of our previous work and on some consistent results coming from Dahl-Fitjar and Rodriguez-Pose (2011)[2], we challenge this view and consider that in specific cases (e.g. Spain and perhaps other less dynamic economies), firms do better in focusing their efforts on either one or the other approach as combining the two would lead them to waste of resources and efficiency losses. And more globally, we expect STI drivers to be significantly stronger than DUI drivers as an effect of the new economy in which the transfer of tacit knowledge (DUI practice) may lead to the repetition and/or incremental improvement of old routines, whereas codified knowledge generation and transfer may lead to more radical innovation processes.

2.3 The effect of product and process innovation on firm performance

The product and process division of innovation is a widely known typology, commonly used by scholars, practitioners and policy makers (Abernathy & Utterback, 1978; Kotabe & Murray, 1990). Evangelista and Vezzani (2010) claim that product innovation is expected to affect positively firm performance due to the technological novelty and a higher sophistication level (i.e., quality) of the new product. Similarly, the authors hold that process innovation yields efficiency and productivity gains attributable to the introduction of better performing ways of producing (pre-existing) products. Indeed, new products generate monopolistic rents, when innovation allows a product to be differentiated for its new features and to be preferred by consumers over other goods/services. However, new processes bring novel means to produce (more) at a lower cost. Either product or process innovation (or both together) can trigger economies of scope and scale, respectively, which in turn lead to superior firm performance.

In this line of thinking, we argue that product and process innovation (or simultaneously both together) improve firm performance by allowing an organization to charge a price

[2] In this work, the DUI drivers are irrelevant when taken within the local/regional production system, whereas become much more meaningful in interactions with suppliers and clients across national boundaries.

premium for successful differentiation (i.e., product innovation) and/or to reduce costs by applying new manufacturing/logistics/commercialization efficient activities (i.e., process innovation).

Hypothesis 2a: Both product and process innovation have a positive effect on firm performance.

But, how do companies combine these two innovation types (i.e., product and process) and how does this choice influence firm performance? Pisano and Wheelwright (1995) found that a stable development of product and process innovation resulted in a continuous launch of new products, a faster market penetration and a larger sales revenue from complex products. The strategic focus, effort and expenditure devoted to product and process innovation often changes over time within an organization. Recent studies show that the combination of both innovation types over time is dynamic and firms which handle effectively the weights of this combination yield sustained above-average performance (Damanpour, Walker, & Avellaneda, 2009).

The very-early and very-mature stages in the firm life-cycle seem to be more attractive for product innovation (i.e. exploration phase), whereas the period in-between these two stages appears to be more appropriate to benefit from scale economies and efficiency gains by implementing new process systems (i.e. exploitation phase). Scarce resources inhibit firms to innovate permanently in generating new products and processes simultaneously. Few companies are capable of combining skillfully both innovation types over time and succeeding in the marketplace (the so-called ambidexterity).

In general, the relevance of these two innovation types is different in each of the firm life-stages of the company. Our conjecture is that profits coming from each type of innovation do not accrue to the firm at the same speed. We expect that process innovation will yield firm profits in a shorter period of time than product innovation, because it may take longer to obtain a threshold beyond which the profit for a new product becomes positive. This is due to the high market uncertainty and slow assimilation by customers inherent to new and complex products.

Hypothesis 2b: The effect of process innovation (i.e., efficiency/scale economies) on firm performance is more immediate than the effect of product innovation (i.e., differentiation/scope economies).

3 Methodology

3.1 Database

We tested our hypotheses with firm-level data from the Spanish Technological Innovation Panel (PITEC). This panel survey is based on the Community Innovation Survey (CIS) and provides annual information on the innovation activities of a large sample of Spanish firms, allowing the study of how the changes in different modes of innovation are related to the heterogeneity in innovation outputs and firm performance over time.[3] The data are collected by the Spanish National Institute of Statistics (INE).

Although PITEC data are available from years 2003 to 2009, some variables of our interest in this study have information from 2004 onwards. Thus, our sample consists on firms that answered to the panel survey at least one year since 2004, which means that our dataset is an unbalanced panel.[4] In order to assure that data on organizational performance corresponds to substantial growth, we excluded observations from firms that were less than 10 employees. We also excluded outlier observations from firms with excessively large growth rates (the percentage of growth larger than 100%) and observations from firms that have suffered sudden employment changes resulted from a merger or acquisition process, a high labour turnover, a layoff, or the impact of the crisis, among other reasons. Finally, we included only firms from the manufacturing and services industries.

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[3] It is worth noting that the panel survey started in 2003 with a representative sample of firms with 200 or more employees, and an initial sample of firms with intramural R&D expenditures which was enlarged in 2004 and 2005 as a result of improvements in the identification of firms undertaking R&D activities. In 2004, the panel was expanded to include a sample of firms with less than 200 employees that reported external R&D expenditures but not intramural R&D expenditures, and a representative sample of firms with less than 200 employees that were not involved in any type of R&D activities. Overall, the panel has covered a sample of 12,817 Spanish firms over the period 2003-2009; however, some firms have dropped out from the sample because they have either disappeared (e.g., due to death, merger or acquisition), refused to continue collaborating, or been unreachable, among other reasons. Thus, the last collection of data (i.e. in 2009) corresponds to 10,891 firms.

[4] However, given that the independent variables in this study are lagged one or two years, the initial data for the dependent variables corresponds to 2005 or 2006, respectively.

The resulting sample is composed of 8,681 firms over an average period of 3.9 years, which makes a total sample of 33,789 observations.

3.2 Measurement of variables

3.2.1 STI and DUI-modes of learning

The *STI learning mode* is commonly identified by the use of scientific and technological knowledge (Jensen et al., 2007). More specifically, this mode requires investing in R&D activities to generate the knowledge needed to create new combinations or possibilities, hence its prevalence in new and high technology industries. As in previous studies, our measures of STI-mode of learning are based on standard indicators used in innovation studies. The first variable we use to capture the STI-mode of learning is intramural R&D expenses as a percentage of the annual turnover in the last year. The second variable is R&D personnel, including consultants working on site, as a percentage of total employment in the last year. The third and final variable is external R&D as a percentage of the annual turnover in the last year.

In contrast, the *DUI-mode of learning* is based on the literature on innovation systems and organizational learning which differentiate between rigid and bureaucratic organizations and those that are flexible and have a greater capacity to interact, learn and adapt (Jensen et al., 2007; Levinthal & March, 1993; Lundvall, 1992). We used three variables to capture the propensity of the firm to be more flexible and adaptable as a proxy of its capacity to learn by doing, using and interacting. The first variable indicates whether the firm has implemented new business practices for organising procedures during the last three years, such as supply chain management, business reengineering, knowledge management, lean production, or quality management. The second variable indicates whether the firm has implemented new methods of organising work responsibilities and decision making during the last three years, such as the first use of a new system of employee responsibilities, team work, decentralisation, or education/training systems. The third variable indicates whether the firm has implemented new methods of organising external relations with other firms or public institutions during the last three years, such as the first use of alliances, partnerships, outsourcing or sub-contracting.

A principal component analysis (PCA) with varimax rotation was conducted to assess convergent and discriminant validity of the constructs defined above (Floyd &

Widaman, 1995). The results of this analysis are shown in Table 1. Using the Kaiser criterion we retained all factors with eigenvalues greater than 1.0 (Kaiser, 1960) and extracted the two first factors which account for 64.85% of total variance.[5] A factor structure that is consistent with our constructs of STI and DUI-mode of learning emerged from these two factors. The first factor was strongly and positively related to variables of STI mode of learning, while the second factor was strongly and positively related to variables of DUI mode of learning.[6] Once construct validity was confirmed, we proceeded to estimate measures of our STI and DUI constructs using standardized scale indicators, and we assessed the internal consistency of the resulting scales using Cronbach's alpha (Cronbach, 1951). In both cases, the Cronbach alpha was above 0.70, which provides evidence of strong internal consistency of the variables employed to measure each construct (Hair et al., 2009).

3.2.2 Product and process innovation

Product innovation (Product) is measured by using four variables. The first one indicates whether the firm has introduced new or significantly improved goods during the last three years (from *t-2* to *t*).[7] The second one indicates whether the firm has introduced new or significantly improved services during the last three years. The third one is a combination of the two previous questions that indicates whether the firm has introduced new or significantly improved products (i.e., goods or services). Finally, a variable captures the novelty of product innovations as the percentage of the total turnover in the last year from new or significantly improved products introduced during the last three years that were new to your market.

Process innovation (Process) is measured by using four variables too. The first one indicates whether the firm has introduced new or significantly improved methods of producing goods or services during the last three years. The second one indicates whether the firm has introduced new or significantly improved logistics, delivery or distribution methods for its goods or services during the last three years. The third one indicates whether the firm has introduced new or significantly improved supporting

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[5] Similarly, the *scree test* (CATTEL, 1966), based on examining the graph of eigenvalues and looking for the natural break point from which the curve flattens out, suggests retaining two factors.

[6] Factor loadings for all variables within the same construct were above 0.4, and no cross-loadings between factors were found.

[7] This excludes the simple resale of new goods or services, and changes of a solely aesthetic nature.

activities for its processes during the last three years, such as maintenance systems purchase operations, accounting, and computing. Finally, as a combination of the three previous questions, a variable indicates whether the firm has introduced any process innovation.

We performed a PCA with varimax rotation to determine whether these variables shared commonalities across the two different dimensions we are interested in, namely product and process innovation. Table 2 shows that 58.59% of the variance is explained by the two first factors which have eigenvalues greater than 1.0. The results for the factors retained provide evidence of construct validity that is consistent with our concepts of product and process innovation. More specifically, the first factor was highly and positively related to all the variables defined as indicators of product innovation, while the second factor was highly and positively related to the variables defined as indicators of process innovation. Accordingly, we proceeded to estimate measures of product and process innovation as standardized scale indicators. The reliability of the scales was assessed using Cronbach’s alpha. The two constructs showed good reliability with Cronbach’s alphas of 0.74 and 0.75, respectively.

3.2.3 Firm performance

Due to the economic impact of expanding firms, growth have been considered as one of the most reliable and valid measures of performance used in the extant literature (Delmar, 2006). Therefore, we chose firm growth in the last year as our dependent variable to capture organizational performance. More specifically, we assessed organizational performance in terms of annual sales change (*ΔSales*) since this has been found to be the most common way to measure firm performance by managers and entrepreneurs (Weinzimmer, Nystrom, & Freeman, 1998), apart from being a good indicator to capture short and long term growth (Coad & Hölzl, 2012). Annual sales change was computed as a relative value as follows:

$$\Delta \text{Sales}_{i,t} = \left(\frac{\text{Sales}_{i,t}}{\text{Sales}_{i,t-1}} \right) \times 100 \tag{1}$$

Where $Sales_{i,t}$ is the sales size of firm *i* at year *t* in Euros. Given that monetary values of sales are influenced by inflation, this variable was adjusted for the national change in prices of domestically produced goods and services (GDP deflator, 2008=100) at the aggregate division level of the NACE Rev.2 industry classification.[8]

3.2.4 Control variables

We also added control variables for other factors that may influence firm innovation and performance and that have been commonly used in previous studies (Dahl Fitjar & Rodríguez-Pose, 2011; Damanpour et al., 2009; Davidsson, Achtenhagen, & Naldi, 2007; Díaz-Díaz, Aguiar-Díaz, & De Saá-Pérez, 2008; Grimpe & Sofka, 2009). First, we controlled for the size of the firm in the previous year which, consistent with the nature of the dependent variable, was measured by the total firm sales in Euros (*Sales size*). As in the case of the annual sales change, this variable was deflated at the aggregate division level of the NACE rev. 2 industry classification (GDP deflator, 2008=100). Second, we controlled whether the firm was part of an enterprise group (*Enterprise group*). Third, a variable is added to control whether the firm is in the manufacturing industry (*Manufacturing firm*). Fourth, we add a variable to control whether the firm operates in a technologically intensive industry according to the Eurostar's classification of technology intensity based on NACE rev. 2 at 3-digit level (*Technological firm*). Fifth, we control whether the firm's headquarters are located in Spain (*Spanish*). Sixth, we distinguish between public and private by controlling whether the firm is mainly private owned. Seventh, given that growth patterns and innovation activities may differ between younger and older firms, the age of the firms is also added as control (*Firm age*). The firm's age is computed as the number of years from the founding year. Eighth, as innovation activities may be influenced by spillovers from other firms generating knowledge, we control whether the firm is located in a science park (*Science park*).

As the panel survey includes different samples of firms, we added dummies indicating the sample to which the firm belongs. The baseline category corresponds to the sample of firms with less than 200 employees that were not involved in any type of R&D activities.[9] Finally, we also control for the year of the observation since there might be

[8] The NACE Rev 2 division level is composed of 38 industry categories.

[9] Sample 1 corresponds to firms with 200 or more employees, while sample 2 corresponds to firms with intramural R&D expenditures. Sample 3 is composed of firms that qualify in both Sample 1 and Sample 2. Sample 4 corresponds to firms with less than 200 employees that reported external R&D expenditures but not intramural R&D expenditures. And finally, Sample 5 corresponds to a representative sample of

external changes that affect the organizational performance. In this case, we included dummies for years 2005 to 2008. The year 2009 is the baseline category since in this year Spain has been strongly affected by the economic crisis.

3.2.5 Empirical model

Our conceptual model posited that the use of STI and DUI learning modes influence the firm's innovation outcomes with a stronger impact of STI on product innovation and a stronger impact of DUI on process innovation. Likewise, the model suggests that innovation outcomes influence organization performance. Because product and process innovation are not an immediate outcome of STI and DUI learning modes, and because the impact of innovation outcomes on performance may take time, we lagged the effects of the explanatory variables. Accordingly, the basic empirical model takes the following form:

$$Y_{\mathrm{i,t}} = \alpha + \beta X_{\mathrm{i,t-1}} + \gamma Z_{i,t} + (u_i + \varepsilon_{i,t}) \qquad (2)$$

where *Y* represents the dependent variable that can be either the firm's performance or innovation output. While *i* denotes firm, *t* denotes the time period. *X* represents the vector of independent variables that explains the corresponding dependent variable. *Z* represents the vector of control variables included in the model, and ε is an idiosyncratic disturbance term that changes across firms and time.

The functional form above reflects the longitudinal nature of the data, which is ideal to observe the dynamic impact of changes over time. Given that most control variables included in the model are time-invariant characteristics, employ a random effects model estimated by generalized least squares. Thus, we assumed that all firms have the same intercepts and slopes, and that the differences among firms and time periods are captured by the variance of the error term represented by *u*.

firms with less than 200 employees that were not involved in any type of R&D activities. Note that these criteria to define firms from each sample refers to the year that they entered the panel.

4 Results

4.1 Descriptive statistics

Table 4 briefly presents the descriptive statistics of the sample and the correlation matrix for all the variables included in the analysis. On average, the sample exhibits an annual sales change of -2.46% during the period of analysis. This variable ranges from -99.96% to 102.70%. Since the explanatory variables were estimated as standardized scale indicators (i.e. product and process innovation, and STI and DUI learning modes), they have a zero mean. While 43% of the sample is part of an enterprise group, the proportion of observations belonging to firms from manufacturing and technology intensive industries is 61% and 33%, respectively. 86% of the sample is composed of firms that have their headquarters in Spain. Almost all firms are private (98% of the sample), whereas a small proportion are located in science parks (3%). Finally, the mean age of the firms included in sample is 27 years.

4.2 The impact of STI and DUI modes on innovation types

The impact of the STI and DUI modes of learning on the firm's product and process innovation is shown in Table 5 and Table 6, respectively. While Model 1 includes the main dependent variables with a one-year lag, Model 2 includes them with a two-year lag.

The results in Table 5 show that, in general, both the construct measuring the STI mode of learning and the construct measuring the DUI mode of learning have a positive impact on product innovation (Model 1 and 2). Indeed, such impact is significant at the 0.001 level in all cases (i.e., using either a one-year lag or a two-year lag). Also as expected, the impact of STI on product innovation is stronger than the impact of DUI, and the difference between these coefficients is significant at the 0.001 level according to a Wald test of simple and composite linear hypotheses (*Prob.* > *F* = 0.000). This suggests that the STI mode of learning contributes to the product innovation outcome more than the DUI mode of learning. Interestingly, the interaction between STI and DUI modes at year *t*-1 has a negative impact on product innovation at year *t* which is significant at the 0.01 level. This negative impact is also significant at the 0.05 level when we use a two-year lag.

In contrast, the results shown in Table 6 indicate that STI and DUI learning modes have a significant and positive impact on process innovation too. The coefficients are significant at the 0.001 level using both a one-year lag and a two-year lag. In this case, the impact of DUI is stronger than the impact of STI. A Wald test of simple and composite linear hypotheses confirms that the contribution of the DUI mode of learning to the process innovation outcome is significantly higher than that of the STI mode of learning at the 0.001 level (*Prob.* > *F* = 0.000). Finally, the interaction between STI and DUI modes of learning at year *t*-1 has a negative impact on process innovation at year *t* which is significant at the 0.05 level. However, this negative impact becomes non-significant when we use a two-year lag. In any case, these findings suggest there are not complementarities between both modes of learning with regards to process innovation.

In sum, our findings suggest that STI and DUI modes of learning, each taken separately, have a positive impact on both product and process innovation, and therefore Hypothesis 1a can be accepted. We also show that the combination of STI and DUI modes within the organization does not add relevant value on process and product innovation, which is consistent with Hypothesis 1c. The results also supports hypothesis 1b, which suggests that the DUI mode of learning has a stronger effect on process innovation compared to the STI mode of learning, while the latter has a higher effect on product innovation than the former.

4.3 The effect of product and process innovation on firm performance

Table 7 shows the impact of product and process innovation on firm performance. With significance level of 0.05, one standard deviation increase in the product innovation outcome at year *t*-1 raises by 0.5 our measure of firm performance, organization's sales growth rate at year *t*. This impact seems to be stronger when we use a two-year lag. In particular, one standard deviation increase in the product innovation outcome at year *t*-2 raises the organization's sales growth rate at year *t* by 0.8, and this impact is significant at the 0.001 level. In contrast, one standard deviation increase in the process innovation outcome at year *t*-1 significantly raises the organization' sales growth rate at year *t* by 0.6 at the 0.01 level. However, this impact becomes slightly weaker when we use a two-year lag since one standard deviation increase in the process innovation outcome at year *t*-2 raises the organization's sales growth rate at year *t* only by 0.6.

As the results suggest, the impact of process innovation on sales growth using a one-year lag seems to be stronger than the impact of product innovation, while the impact of product innovation on sales growth using a two-year lag seems to be stronger than the impact of process innovation. That is, process innovation seems to have an immediate impact which is stronger in the short term compared to product innovation, or said in other words the highest impact of product innovation is not immediate and might take a long time compared to process innovation. However, according to a Wald test, the difference between the coefficients is not significant in either case (*Prob.* > *F* = 0.742 and *Prob.* > *F* = 0.498, respectively). That is, there is not a differentiated impact of product and process innovation on sales growth.

Consequently, the results described above allow us to accept hypothesis 2a, which states that both product and process innovations have a positive effect on firm performance, but we cannot accept hypothesis 2b, which suggests that process innovation exerts an immediate effect firm performance.

5 Conclusion and implications

Several authors hold that there is still no consensus either on the drivers of innovation or on the impact of innovation on firm performance (Evangelista & Vezzani, 2010; Hemert et al., 2012; Stam & Wennberg, 2009). We have investigated the relationships among the different components of the “innovation black box”, namely the learning modes, innovation types and performance. We believe that our exploratory findings add new insights to the field of innovation and value creation.

Firstly, we have shown that reconciling STI and DUI learning modes is a complex and risky task. STI and DUI practices do not only rely on firm internal activities, but also on firm external collaboration. If STI and DUI (internal and external) practices are not well handled within an organization, innovation outputs can even be negatively affected. Secondly, STI and DUI exert separately a positive effect on innovation, which supports previous findings in the literature. But the magnitude of each effect STI or DUI varies for each type of innovation (i.e., product and process innovation). More specifically, the separate influence of STI on product innovation is more pronounced than that of DUI, whereas the effect of STI on process innovation is lower than that of DUI. Interestingly, the combined effect of STI and DUI does not seem to improve each of the separate effects. What is more, product and process innovation are unexpectedly hampered when a company undertakes both STI and DUI activities together. On the whole of Spain, this result confirms our previous study based on a smaller sample of Basque firms, and partly also Dahl's and Rodriguez-Pose's (2011) research. In general, it seems that the firms that are capable of generating a significant innovation output may decide to focus on either STI or DUI practices, as it is recognized in Aslesen et al. (2011). In particular, diverging from Jensen et al. (2007), our study indicates that these firms cannot rely on the two modes altogether, since this mixed approach can lead to inefficiency and ineffectiveness. Thirdly, strategic choices on product and process innovation may change over time. We found the existence of a positive effect of process and product innovation on firm performance, as measured by sales growth. Lastly, most empirical studies have analyzed this phenomenon from a static perspective. We have applied a multi-period approach by using a large longitudinal data set and conducting panel regression tests in order to verify the relationships among innovation drivers, types and effects comprehended in our broad conceptual model.

Our work is not exempt of limitations. We have created constructs for variables describing learning modes (STI, DUI) and two types of innovation (product and process innovation). Many of the variables used to create such constructs are dichotomous. The availability of a larger number of continuous variables would refine the constructs used in this study. Although we believe that the meaning and significance of our results would not change much, the use of continuous variables can provide a more accurate measure of the intensity of the constructs. In addition, the use of additional performance indicators (i.e., profits, returns) and the application a longer time span for capturing the dynamics of value creation would add robustness to our results (i.e., we used a reasonable average 3-year period for different cohorts, but preferably, we would desire a longer study period).

Despite the shortcomings mentioned earlier, we can provide at least two relevant policy implications. On the one hand, policy makers should recognize that innovation benefits come from both product differentiation and cost efficiencies. Therefore, not only product innovation is important, but also process innovation contributes to business performance as it has been shown in our results. Most policy actions have fostered programs designed to improve the STI capacity of firms, particularly SMEs, neglecting the relevance of the DUI approach discussed in our paper. Company owners and managers can be more effective in capitalizing their innovation efforts when they interact not only with scientists, but also customers, suppliers, competitors, end-users of their products, and other many stakeholders (e.g., government authorities, NGOs). Both firm internal and external collaboration matters. But caution is recommended, because managing all these networks simultaneously together may be detrimental to the firm, as it has been shown in this paper. On the other hand, there is huge unawareness on the value generated by subsidies granted to improve the innovation capacity of firms (i.e., product and process innovation capacity). Empirical evidence from the literature shows that different types of innovation (process and product innovation) are positively linked to business performance. Nonetheless, the additionality of these programs should be properly assessed by monitoring regularly the extent to which the product or/and process innovation activity supported by subsidies generate value to the firm.

6 References

Abernathy, W.J., & Utterback, J.M., 1978. Patterns of industrial innovation. *Technology Review*, *80*(7), 40–47.

Arrow, K.J., 1962. Economic Welfare and the Allocation of Resources for Invention. In Universities-National-Bureau-Committee-for-Economic-Research (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609–626). Princenton, NJ: Princeton University Press.

Asheim, B.T., & Coenen, L., 2005. Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, *34*(8), 1173–1190. doi:10.1016/j.respol.2005.03.013.

Aslesen, H., Isaksen, A., & Karlsen, J., 2011. Modes of Innovation and Differentiated Responses to Globalisation—A Case Study of Innovation Modes in the Agder Region, Norway. *Journal of the Knowledge Economy*, 1–17. doi:10.1007/s13132-011-0060-9.

Audretsch, D.B., & Keilbach, M., 2008. Resolving the knowledge paradox: Knowledge-spillover entrepreneurship and economic growth. *Research Policy*, *37*(10), 1697–1705.

Becattini, G., Bellandi, M., & Propris, L. D. (Eds.), 2009. *A Handbook of Industrial Districts*. Edward Elgar Pub.

Chen, J., Chen, Y., & Vanhaverbeke, W., 2011. The influence of scope, depth, and orientation of external technology sources on the innovative performance of Chinese firms. *Technovation*, *31*(8), 362–373. doi:10.1016/j.technovation.2011.03.002

Coad, A., & Hölzl, W., 2012. Firm growth: empirical analysis. In M. Dietrich & J. Krafft (Eds.), *Handbook On The Economics And Theory Of The Firm*. Edward Elgar, Cheltenham.

Cohen, W.M., & Levinthal, D.A., 1989. Innovation and Learning: The Two Faces of R&D. *The Economic Journal*, *99*(397), 569–596.

Cooke, P., & Morgan, K., 1996. The regional innovation system in Baden-Wurttemberg. *International Journal of Technology Management*, *9*(3-4), 394–429.

Cronbach, L. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334. doi:10.1007/BF02310555.

Dahl Fitjar, R., & Rodríguez-Pose, A. 2011. Firm collaboration and modes of innovation in Norway. *Research Policy*. doi:10.1016/j.respol.2012.05.009.

Damanpour, F., Walker, R.M., & Avellaneda, C. N. 2009. Combinative Effects of Innovation Types and Organizational Performance: A Longitudinal Study of Service Organizations. *Journal of Management Studies*, *46*(4), 650–675. doi:10.1111/j.1467-6486.2008.00814.x.

Davidsson, P., Achtenhagen, L., & Naldi, L. 2007. What Do We Know About Small Firm Growth? In S. Parker (Ed.), *The Life Cycle of Entrepreneurial Ventures*, International Handbook Series on Entrepreneurship (Vol. 3, pp. 361–398). Springer US. Retrieved from http://www.springerlink.com/content/m8757483m01565t1/abstract/.

Davidsson, P., & Wiklund, J. 2000. Conceptual and Empirical Challenges in the Study of Firm Growth. In D. L. Sexton & H. Landstrom (Eds.), *Handbook of Entrepreneurship* (pp. 26–44). Blackwell, Oxford, UK.

Delmar, F. 2006. Measuring growth: methodological considerations and empirical results. In P. Davidsson, F. Delmar, & J. Wiklund (Eds.), *Entrepreneurship and the Growth of Firms* (pp. 62–84). Edward Elgar, Cheltenham.

Díaz-Díaz, N.L., Aguiar-Díaz, I., & De Saá-Pérez, P. 2008. The effect of technological knowledge assets on performance: The innovative choice in Spanish firms. *Research Policy*, *37*(9), 1515–1529. doi:10.1016/j.respol.2008.06.002.

Evangelista, R., & Vezzani, A. 2010. The economic impact of technological and organizational innovations. A firm-level analysis. *Research Policy*, *39*(10), 1253–1263. doi:10.1016/j.respol.2010.08.004.

Floyd, F.J., & Widaman, K.F. 1995. Factor analysis in the development and refinement of clinical assessment instruments. *Psychological Assessment*, *7*(3), 286–299. doi:10.1037/1040-3590.7.3.286.

Gertler, M.S., & Asheim, B.T. 2006. 11. The Geography of Innovation: Regional Innovation Systems. *The Oxford Handbook of Innovation* (1st ed., Vol. 1, pp. 291–318). Oxford, England: Oxford University Press. Retrieved from http://www.oxfordhandbooks.com/oso/public/content/oho_business/9780199286805/oxfordhb-9780199286805-chapter-11.html.

González-Pernía, J.L., Peña-Legazkue, I., & Vendrell-Herrero, F. 2012. Innovation, entrepreneurial activity and competitiveness at a sub-national level. *Small Business Economics, 39*(3), 561–574.

Greunz, L. 2005. Intra- and inter-regional knowledge spillovers: Evidence from European regions. *European Planning Studies*, *13*(3), 449–473. doi:10.1080/09654310500089746.

Greve, H.R. 2003. A Behavioral Theory of R&D Expenditures and Innovations: Evidence from Shipbuilding. *Academy of Management Journal*, *46*(6), 685–702. doi:10.2307/30040661

Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics*, *10*(1), 92–116.

Grimpe, C., & Sofka, W. 2009. Search patterns and absorptive capacity: Low- and high-technology sectors in European countries. *Research Policy*, *38*(3), 495–506. doi:10.1016/j.respol.2008.10.006

Hair, J.F., Black, W.C., Babin, B.J., & Anderson, R.E. 2009. *Multivariate Data Analysis* (7th ed.). Prentice Hall.

Hemert, P., Nijkamp, P., & Masurel, E. 2012. From innovation to commercialization through networks and agglomerations: analysis of sources of innovation, innovation capabilities and performance of Dutch SMEs. *The Annals of Regional Science*. doi:10.1007/s00168-012-0509-1.

Isaksen, A., & Karlsen, J. 2010. Different Modes of Innovation and the Challenge of Connecting Universities and Industry: Case Studies of Two Regional Industries in Norway. *European Planning Studies*, *18*(12), 1993–2008. doi:10.1080/09654313.2010.516523.

Jensen, M.B., Johnson, B., Lorenz, E., & Lundvall, B.Å. 2007. Forms of knowledge and modes of innovation. *Research Policy, 36*(5), 680–693.

Kaiser, H.F. 1960. The Application of Electronic Computers to Factor Analysis. *Educational and Psychological Measurement*, *20*(1), 141–151.

Kline, S.J., & Rosenberg, N. 1986. An Overview of Innovation. In R. Ladau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–306). Washington, DC: National Academy Press. Retrieved from http://www.nap.edu/openbook.php?record_id=612&page=275.

Kotabe, M., & Murray, J.Y. 1990. Linking Product and Process Innovations and Modes of International Sourcing in Global Competition: A Case of Foreign Multinational Firms. *Journal of International Business Studies*, *21*(3), 383–408. doi:10.1057/palgrave.jibs.8490339.

Levinthal, D.A., & March, J.G. 1993. The Myopia of Learning. *Strategic Management Journal*, *14*(2), 95–112.

Lundvall, B.A. (Ed.). 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter Pub Ltd.

Nelson, R.R. 1993. *National Innovation Systems: A Comparative Analysis*. Oxford University Press.

Parrilli, M.D., & Asheim, B.T. (Eds.). 2012. *Interactive Learning for Innovation: A Key Driver within Clusters and Innovation Systems*. Palgrave Macmillan.

Parrilli, M.D., & Elola, A. 2011. The strength of science and technology drivers for SME innovation. *Small Business Economics*, 1–11. doi:10.1007/s11187-011-9319-6.

Pisano, G.P., & Wheelwright, S.C. 1995. The New Logic of High-Tech R&D. *Harvard Business Review*, *73*(5), 93–105.

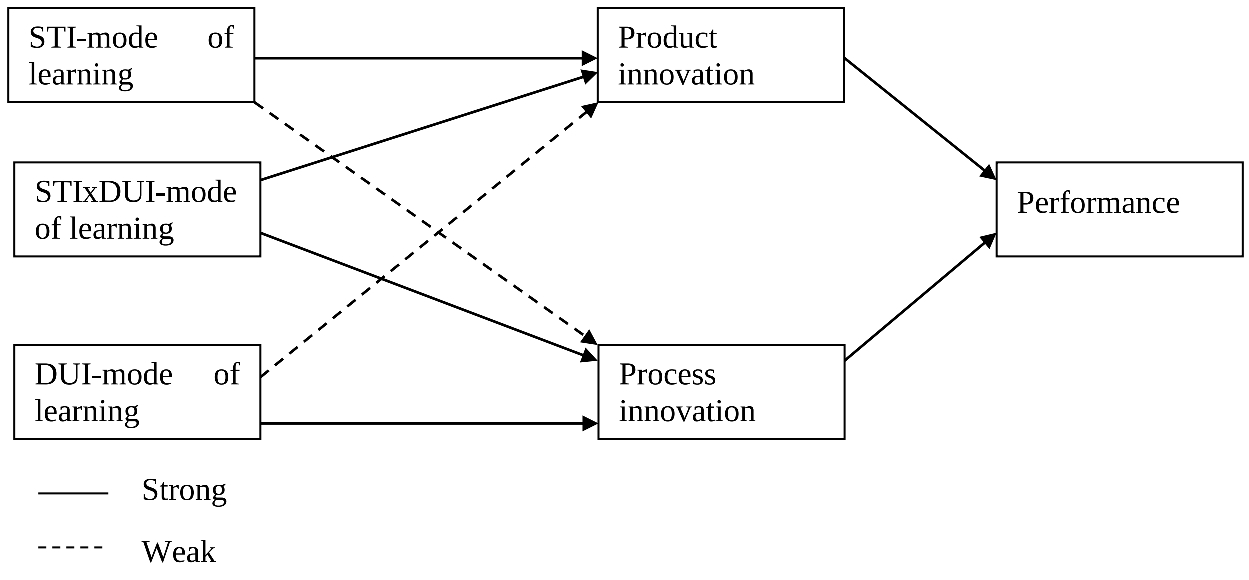
Stam, E., & Wennberg, K. 2009. The roles of R&D in new firm growth. *Small Business Economics*, *33*(1), 77–89. doi:10.1007/s11187-009-9183-9

Thornhill, S. 2006. Knowledge, innovation and firm performance in high- and low-technology regimes. *Journal of Business Venturing*, *21*(5), 687–703.

Weinzimmer, L.G., Nystrom, P.C., & Freeman, S.J. 1998. Measuring Organizational Growth: Issues, Consequences and Guidelines. *Journal of Management*, *24*(2), 235–262. doi:10.1177/014920639802400205.

Figures

Figure 1: Conceptual model



Tables

Table 1: STI- and DUI-mode of learning, factor analysis

			Rotated factor loadings		**Cronbach's alpha of standardized scales**
	Variables	**Measurement**	Factor 1	Factor 2	
STI	Intramural R&D expenditures	As a percentage of sales	0,9014	0,0488	
	Intramural R&D personnel	As a percentage of total personnel	0,877	0,0941	0,7299
	External R&D expenditures	As a percentage of sales	0,6195	0,0259	
DUI	New business practices	0- No / 1- Yes	0,0541	0,8335	
	New methods of organising work	0- No / 1- Yes	0,0354	0,8503	0,7087
	New methods of organising external relations	0- No / 1- Yes	0,1529	0,684	
Percentage of variance explained			0,3322	0,3163	

Table 2: Product and process innovation

Construct	Variables	Measurement	Rotated factor loadings		Cronbach's alpha of standardized scales
			Factor 1	Factor 2	
Product	New goods	0- No / 1- Yes	0.8401	0.1673	0.7407
	New services	0- No / 1- Yes	0.5240	0.2537	
	New products (any of the above)	0- No / 1- Yes	0.9139	0.2104	
	New products to market	as a percentage of sales	0.6316	-0.0524	
Process	New production methods	0- No / 1- Yes	0.2939	0.6767	0.7502
	New logistic systems	0- No / 1- Yes	0.0723	0.6125	
	New support activities	0- No / 1- Yes	0.0786	0.7611	
	New processes (any of the above)	0- No / 1- Yes	0.2072	0.8834	
Percentage of variance explained			0.2944	0.2915	

Table 3: Description of the control variables

Control variables	Description	Measurement
Sales size	Sales of the firm in the previous year adjusted for inflation	Ln(Sales$_{t-1}$)
Enterprise group	The firm is part of an enterprise group	0- No / 1- Yes
Manufacturing firm	The firm's main activity falls within the manufacturing sector	0- No / 1- Yes
Technological firm	The firm's main activity falls within a high or medium-high R&D intensive sector	0- No / 1- Yes
Spanish firm	The firm's headquarters is located in Spain	0- No / 1- Yes
Private firm	The firm is private owned	0- No / 1- Yes
Firm age	Age of the firm in a given year	Current year - year of foundation + 1
Science park	The firm is located in a science or technology park	0- No / 1- Yes
Sample1-5	Dummy variables indicating the sample to which the firm belongs. The baseline category is the sample of firms with less than 200 employees that were not involved in any type of R&D activities	0- No / 1- Yes
Y2005-09	Dummy variables indicating the year to which the observation belongs to. Year 2009 is the baseline category	0- No / 1- Yes

Table 4: Descriptive statistics and correlation matrix

Variable		Obs.	N	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	$\Delta Sales_{i,t}$	33,789	8,681	-2.46	22.14	-99.96	102.70	1												
(2)	$Product_{i,t-1}$	33,789	8,681	0.00	0.75	-0.73	2.08	0.03	1											
(3)	$Process_{i,t-1}$	33,789	8,681	0.00	0.76	-0.76	1.53	0.02	0.39	1										
(4)	$STI_{i,t-1}$	33,789	8,681	0.00	0.71	-0.34	11.60	0.09	0.29	0.11	1									
(5)	$DUI_{i,t-1}$	33,789	8,681	0.00	0.78	-0.65	1.66	0.04	0.31	0.39	0.16	1								
(6)	Sales $size_{i,t-1}$	33,789	8,681	16.43	1.75	9.19	23.23	0.01	-0.01	0.13	-0.26	0.07	1							
(7)	Enterprise $group_{i,t}$	33,789	8,681	0.43	0.49	0.00	1.00	0.01	0.01	0.07	-0.07	0.06	0.53	1						
(8)	Manufacturing $firm_{i,t}$	33,789	8,681	0.61	0.49	0.00	1.00	-0.09	0.18	0.20	-0.07	0.00	-0.03	-0.06	1					
(9)	Technological $firm_{i,t}$	33,789	8,681	0.33	0.47	0.00	1.00	0.03	0.25	0.09	0.26	0.09	-0.11	0.01	0.21	1				
(10)	Spanish $firm_{i,t}$	33,789	8,681	0.86	0.35	0.00	1.00	0.01	0.01	-0.03	0.08	-0.01	-0.37	-0.48	-0.01	-0.07	1			
(11)	Private $firm_{i,t}$	33,789	8,681	0.98	0.15	0.00	1.00	-0.03	-0.02	0.00	-0.15	-0.03	0.01	0.03	0.16	-0.01	-0.06	1		
(12)	Firm $age_{i,t}$	33,789	8,681	27.15	22.10	1.00	544.00	-0.02	0.02	0.07	-0.13	0.02	0.30	0.08	0.09	-0.05	-0.07	0.02	1	
(13)	Science $park_{i,t}$	33,789	8,681	0.03	0.17	0.00	1.00	0.05	0.08	0.03	0.19	0.07	-0.05	0.02	-0.08	0.08	0.03	-0.07	-0.07	1

Table 5: Impact of STI and DUI modes of learning on product innovation

	(1)	**(2)**
STI $_{i,t-1}$	0.139***	
	(0.006)	
DUI $_{i,t-1}$	0.076***	
	(0.005)	
STIxDUI $_{i,t-1}$	-0.016**	
	(0.005)	
STI $_{i,t-2}$		0.120***
		(0.007)
DUI $_{i,t-2}$		0.078***
		(0.006)
STIxDUI $_{i,t-2}$		-0.014*
		(0.007)
Sales size$_{i,t-1}$	0.052***	0.047***
	(0.005)	(0.005)
Enterprise group$_{i,t}$	0.029**	0.028*
	(0.011)	(0.012)
Manufacturing firm$_{i,t}$	0.071***	0.081***
	(0.014)	(0.015)
Technological firm$_{i,t}$	0.191***	0.201***
	(0.013)	(0.014)
Spanish firm$_{i,t}$	0.042**	0.033*
	(0.015)	(0.016)
Private firm$_{i,t}$	-0.066*	-0.114***
	(0.029)	(0.032)
Firm age$_{i,t}$	0.001**	0.001**
	(0.000)	(0.000)
Science park$_{i,t}$	0.053	0.055
	(0.027)	(0.029)
Sample1	-0.001	0.004
	(0.028)	(0.030)
Sample2	0.550***	0.540***
	(0.023)	(0.025)
Sample3	0.543***	0.533***
	(0.032)	(0.034)
Sample4	0.281***	0.234***

		(0.037)	(0.040)
y2005		-0.048***	
		(0.008)	
y2006		0.004	-0.012
		(0.007)	(0.007)
y2007		-0.048***	-0.043***
		(0.007)	(0.006)
y2008		-0.019**	-0.023***
		(0.006)	(0.006)
Intercept		-1.318***	-1.199***
		(0.080)	(0.084)
N		33,789	25,711
		8,681	8,407
	Within	0.008	0.002
R^2:	Between	0.312	0.284
	Overall	0.263	0.259

Standard errors in parentheses

Level of statistical significance: *** p ≤ .001, ** p ≤ .01, * p ≤ .05, † p ≤ .10

Table 6: Impact of STI and DUI modes of learning on process innovation

	(1)	**(2)**
STI $_{i,t-1}$	0.063***	
	(0.007)	
DUI $_{i,t-1}$	0.125***	
	(0.005)	
STIxDUI $_{i,t-1}$	-0.012*	
	(0.006)	
STI $_{i,t-2}$		0.052***
		(0.008)
DUI $_{i,t-2}$		0.132***
		(0.007)
STIxDUI $_{i,t-2}$		-0.012
		(0.007)
Sales size$_{i,t-1}$	0.086***	0.082***
	(0.005)	(0.005)
Enterprise group$_{i,t}$	0.025*	0.026*
	(0.012)	(0.013)
Manufacturing firm$_{i,t}$	0.157***	0.163***
	(0.014)	(0.015)
Technological firm$_{i,t}$	-0.004	0.003
	(0.013)	(0.015)
Spanish firm$_{i,t}$	0.047**	0.037*
	(0.016)	(0.017)
Private firm$_{i,t}$	-0.084**	-0.098**
	(0.030)	(0.034)
Firm age$_{i,t}$	0.001**	0.001***
	(0.000)	(0.000)
Science park$_{i,t}$	0.023	0.040
	(0.028)	(0.030)
Sample1	0.006	0.014
	(0.028)	(0.031)
Sample2	0.413***	0.392***
	(0.024)	(0.026)
Sample3	0.448***	0.439***
	(0.032)	(0.035)
Sample4	0.323***	0.290***

		(0.037)	(0.041)
y2005		-0.051***	
		(0.008)	
y2006		0.012	-0.005
		(0.007)	(0.008)
y2007		-0.049***	-0.055***
		(0.007)	(0.007)
y2008		-0.030***	-0.034***
		(0.007)	(0.006)
Intercept		-1.774***	-1.682***
		(0.081)	(0.087)
N		33,789	25,711
		8,681	8,407
	Within	0.008	0.002
R^2:	Between	0.312	0.284
	Overall	0.263	0.259

Standard errors in parentheses

Level of statistical significance: *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, † $p \leq .10$

Table 7: The impact of product and process innovation on firm performance

	(1)	(2)
$Product_{i,t-1}$	0.500*	
	(0.202)	
$Process_{i,t-1}$	0.603**	
	(0.191)	
$Product_{i,t-2}$		0.831***
		(0.239)
$Process_{i,t-2}$		0.582**
		(0.225)
Sales $size_{i,t-1}$	-1.346***	-1.915***
	(0.131)	(0.151)
Enterprise $group_{i,t}$	1.734***	1.923***
	(0.368)	(0.433)
Manufacturing $firm_{i,t}$	-3.897***	-4.243***
	(0.354)	(0.414)
Technological $firm_{i,t}$	1.431***	1.134**
	(0.349)	(0.408)
Spanish $firm_{i,t}$	0.961*	0.488
	(0.481)	(0.556)
Private $firm_{i,t}$	-0.705	-0.926
	(0.971)	(1.150)
Firm $age_{i,t}$	0.015*	0.024**
	(0.007)	(0.009)
Science $park_{i,t}$	5.338***	6.253***
	(0.868)	(1.005)
Sample1	5.725***	6.954***
	(0.734)	(0.857)
Sample2	3.500***	3.398***
	(0.622)	(0.733)
Sample3	6.456***	7.715***
	(0.837)	(0.977)
Sample4	2.174*	2.324*
	(0.972)	(1.140)
y2005	17.613***	
	(0.365)	
y2006	19.966***	20.157***

		(0.326)	(0.374)
y2007		19.442***	19.603***
		(0.308)	(0.334)
y2008		9.488***	9.678***
		(0.305)	(0.313)
Intercept		3.335	12.308***
		(2.310)	(2.684)
Observations		33,789	25,711
Cases		8,681	8,407
	Within	0.182	0.200
R^2:	Between	0.025	0.042
	Overall	0.135	0.140

Standard errors in parentheses

Level of statistical significance: *** p ≤ .001, ** p ≤ .01, * p ≤ .05, † p ≤ .10

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